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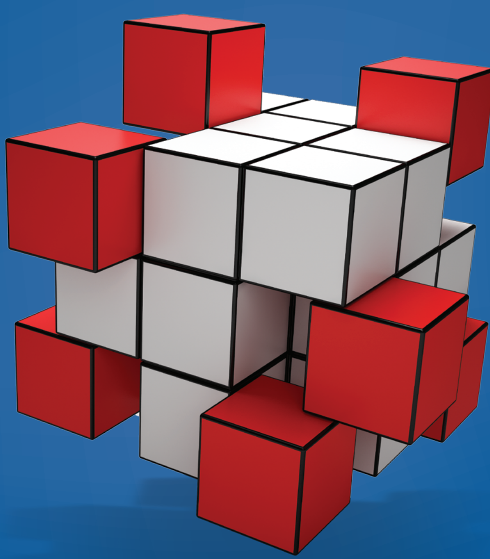
The Intelligent Brain

Course Guidebook

Professor Richard J. Haier
University of California, Irvine



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Professor Richard J. Haier is Professor Emeritus in the School of Medicine at the University of California, Irvine, where he has been teaching and conducting research since 1986. In 1971, he received his B.A. in Psychology from the University at Buffalo, The State University of New York, and in 1975, he received his Ph.D. in Psychology from Johns Hopkins University. Professor Haier was a Staff Fellow at the National Institute of Mental Health from 1976 to 1980, and he was on the faculty of Brown University's Alpert Medical School from 1980 to 1985.

Professor Haier has published more than 135 research articles and book chapters. His main research interest is investigating the structural and functional neuroanatomy of higher cognitive processes, especially intelligence. In 1988, he and his colleagues conducted the first modern functional brain imaging study of intelligence with positron emission tomography (PET) and proposed a hypothesis linking good performance on an intelligence test to efficient brain function. Professor Haier's more recent research with magnetic resonance imaging (MRI) has identified specific brain areas where gray and white matter features correlate to the *g* factor of intelligence and other intelligence factors. In 2007, he and Dr. Rex Jung published an extensive review of all neuroimaging studies of intelligence and proposed a model called the parieto-frontal integration theory (P-FIT) of human intelligence.

Since 1990, Professor Haier has served on the editorial board of *Intelligence*, and in 2009, he was a guest editor for a special issue on neuroimaging studies. He also has reviewed grant proposals related to intelligence for the National Science Foundation. Professor Haier works with cognitive psychologists and other investigators new to intelligence research to ensure awareness of psychometric and conceptual issues necessary for designing

informative neuroimaging studies. This work was the main focus of his service on the editorial board of *NeuroImage* and as a reviewer for *Nature Reviews Neuroscience*, *Psychological Review*, *Psychological Bulletin*, *Journal of Experimental Psychology*, and granting agencies in the United Kingdom, the Netherlands, and Canada.

Major themes of Professor Haier's work for the last 25 years are the application of the powerful techniques of neuroimaging to the study of individual differences in intelligence and the expansion and promotion of interest in the field beyond psychometrics. These ideas were the basis for invited lectures and presentations sponsored by the National Science Foundation, the National Academy of Sciences, the European Molecular Biology Organization, Cold Spring Harbor, the New York Academy of Sciences, the American Enterprise Institute, and La Caixa Foundation in Spain. He also has spoken at numerous academic departments and conferences in the United States and abroad. Professor Haier's research has been funded by the National Institutes of Health, the Office of Naval Research, the MacArthur Foundation, and other private foundations. His work has been featured on *NOVA scienceNOW*, NPR, CNN, and *CBS Sunday Morning* and in numerous newspaper and magazine reports, including those in *Newsweek* and *Time*. In 2009, Professor Haier summarized his intelligence research for the public in an article in *Scientific American Mind.* In 2012, he received the Distinguished Contributor Award from the International Society for Intelligence Research. ■

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INTRODUCTION

LECTURE GUIDES

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The Intelligent Brain

Scope:

The concept of human intelligence is sometimes controversial, but two things are surely true. First, no matter how "intelligence" is defined, you know someone who is not as intelligent as you are. Second, intelligence has something to do with the brain. New neuroscience tools, especially brain imaging, are revealing what a smart brain looks like and helping researchers understand the neural mechanisms of what makes one person learn faster, remember more, and reason better than another.

This course begins with the challenge of defining intelligence for scientific study. Savants show one aspect of specific mental abilities, but there is also strong evidence that all mental abilities have a common general factor of intelligence—called *g*. Measuring *g* and other factors of intelligence depends mostly on IQ-type tests, which the course will explain, including what these tests do and do not measure. Evidence from long-term studies of genius and IQ over the life span will give some insights about the power and value of intelligence tests, especially as we all navigate the complexities of everyday life.

Some popular alternative concepts of intelligence that do not focus on the *g*-factor include practical intelligence and multiple intelligences, but as you will see, the research evidence for their validity is more limited. The role of early childhood experiences on intelligence is also surprisingly controversial, especially because the role of genetics is increasingly well supported by research, as the course will review. The concept of epigenetics is important because it potentially reverses the idea that a genetic basis for intelligence means that intelligence is fixed.

Whether intelligence is mostly influenced by genes or by environmental/cultural factors, any effects must work on the brain's biology. Brain imaging has made major advances to help understand the neural basis of intelligence in adults and in children. This course will review some

of these studies and present several surprising results. These studies also show that measures of intelligence are not meaningless artifacts of statistical methods because test scores are related to specific brain features. This allows a more objective review of older controversies about sex and race differences in mental abilities. The course will update research findings about these persistent controversies. One of the newest mysteries to consider is that average intelligence test scores are slowly increasing around the world for reasons unknown. One hope is that older controversies and newer mysteries can be addressed with novel ways to assess intelligence based on measuring brain processing speed. Another issue of renewed interest from brain imaging studies is how creativity may be related to intelligence.

Overall, the new neuroscience of intelligence research leads inexorably to speculation about whether brain mechanisms can be tweaked to enhance intelligence with brain training or by manipulating neurochemistry or even by genetic engineering. It may be possible not only to raise low intelligence, but also to increase high intelligence to new levels. There are already attempts to do so. These possibilities raise a number of issues for child rearing, education, and social policy. One central issue is whether we have a moral obligation to increase intelligence if we could. Assuming that more intelligence is always better than less, would you take an IQ pill, or prevent your child from taking one? Research on intelligence is progressing so that such choices could be real in the not-so-distant future. ■

What Is Intelligence?

Lecture 1

This course is about the science of intelligence. The course will explore some of the things we know about intelligence and some of the things we are learning; we've already learned a lot, but many mysteries remain, and most of them are surrounded by controversies. In this lecture, you will examine some basic concepts necessary for defining and measuring intelligence, and you will be supplied with a tentative answer to the following question: Where in the brain is intelligence? In addition, you will consider what the new science of intelligence means for you.

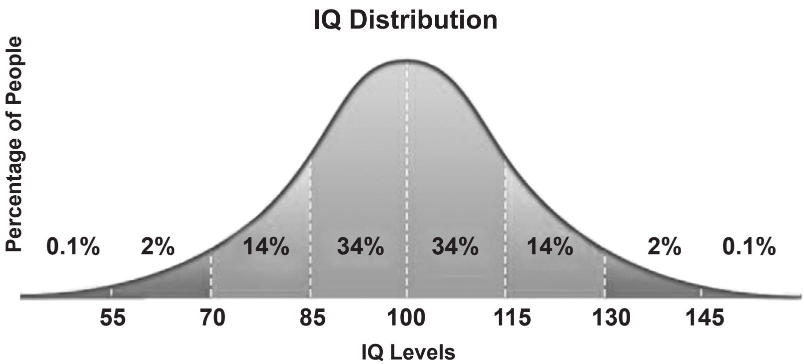
Intelligence and IQ Tests

- The American Psychological Association Task Force on Intelligence defines intelligence in the following way: "Individuals differ from one another in their ability to understand complex ideas, to adapt effectively to the environment, to learn from experience, to engage in various forms of reasoning, to overcome obstacles by taking thought."

- The main element in common to all definitions of intelligence is that it is a general ability. IQ, mental ability, and intelligence are all used in the same way to describe this general ability.

- In every branch of science, definitions of basic concepts evolve over time and get more and more precise as measurements get better and allow finer-grained questions. All of the definitions of intelligence have the same inherent challenge for researchers: How do you measure intelligence to do empirical research? We expect that as measurements improve, the definition of intelligence will become more precise.

- IQ scores are derived from a battery of tests, so the single IQ score actually represents a range of mental abilities. That's why it's a good measure of general intelligence. IQ scores for very large,



random samples of people are normally distributed. Many variables are normally distributed in a large population. These properties are the same regardless of whether we are talking about height, income, or intelligence.

- A normal distribution is also called a bell curve. IQ scores typically have a mean of 100 and a standard deviation of 15; 50 percent of people score above 100, and 50 percent score below 100. The average IQ is 85 to 114, and 68 percent of people fall into this range. Only 16 percent of people have scores of 85 or lower, and 14 percent of people have scores of 115 to 129. The top two percent of people have IQ scores of 130 to 145; these scores are higher than 98 percent of the population. IQ scores over 145 indicate the top 0.1 percent.

- IQ scores predict general learning ability. People with IQs below 80 to 85 generally learn slower and require more concrete, step-by-step instruction. People with IQs over 115 generally learn more abstractly and seek out information on their own. In the middle IQ range, many individuals certainly can learn complex material, but it may take longer with more individual instruction. Keep in mind that these are not perfect relationships, and there are certainly exceptions.

- IQ predicts many real-world things. IQ scores predict not only things like education level, income, and job performance, but

they also predict health and even mortality. However, IQ does not predict many other important things, like happiness, mental illness, honesty, or being a nice or likeable person.

Mental Abilities

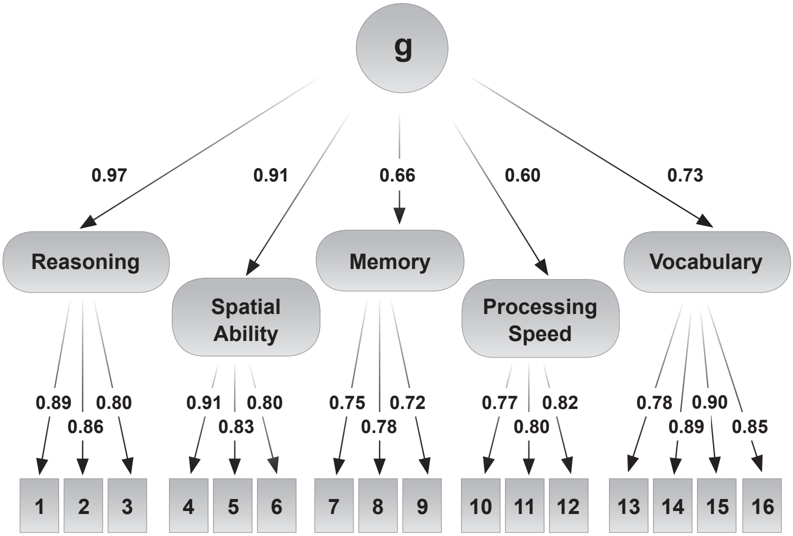
- Researchers have learned that there are many mental abilities. Some are very specific, such as tests of spelling or the ability to mentally rotate 3-D objects; other tests assess more general abilities, such as memory or problem solving.

- Over 100 years of research, we have learned about how such tests relate to each other. We have learned that different mental abilities are not independent: They are all related to each other, and the correlations among mental tests are always positive—which means that if you do well on one kind of mental ability test, you tend to do well on other tests. This is the core finding about intelligence, and it's the basis for most modern research.

- The relationship among mental tests is called the structure of mental abilities. To picture the structure, imagine a three-level pyramid. At the bottom, there is a row of many different tests of specific abilities (16, for example). At the next level up, tests of similar abilities are grouped into more specific factors, such as reasoning, spatial ability, memory, speed of information processing, and vocabulary. Tests one, two, and three, for example, are all reasoning tests; tests seven, eight, and nine are all memory tests. However, all of the more specific factors also are related to each other.

- This is a key finding demonstrated over and over again. It strongly implies that all of the tests and factors derived from individual tests have something in common, and this common factor is called the general factor of intelligence, or *g*, which sits at the highest point on the pyramid.

- Charles Spearman first described *g* over 100 years ago, and it is the basis of most definitions of intelligence used in research. It is not the



same as IQ, but IQ scores are good estimates of *g* because most IQ tests are based on a battery of tests that sample many mental factors.

- We have many mental abilities—from multiplying in your head to picking stocks to naming state capitals. "Intelligence" is a catchall word that means the mental abilities most related to responding to everyday problems and navigating the environment.

- IQ is a test score based on a subset of the mental abilities that relate to everyday intelligence. IQ is a good predictor of everyday intelligence. The *g*-factor is what is common to all mental abilities, and it is a fairly large part of IQ. Whereas everyday intelligence and IQ tests can be influenced by many factors, including social and cultural ones, the *g*-factor is thought to be more biological and genetic.

- Kim Peek was the model for the autistic savant character in *Rain Man*, a 1988 movie with Dustin Hoffman. Kim could answer many kinds of questions for just about any historical figure or event, and

he could answer many other questions based on his ability to recall 7,600 books, which he read by paging through them and scanning each page quickly. Kim had a low IQ and could not work or care for himself, but he had an amazing memory and recall ability. How he did this is not understood, but clearly extraordinary memory is not the same as high intelligence.

- Savants are quite rare. They usually excel at a narrow mental skill to a level that often appears to be in the genius range, but they also typically have low IQs. In many cases, savants have very specific abilities with little if any *g*.

- Examples of savants show that powerful independent abilities can exist, but they also demonstrate the problems that can arise when *g* is lacking. Most people have *g* and independent factors, and two people with the same level of *g* can have different patterns of mental strengths and weaknesses. Savants demonstrate the differences between specific and general mental abilities.

- The IBM computer Watson, which beat two all-time *Jeopardy!* champions, demonstrates a specific ability to analyze verbal information and solve problems based on the meaning of words. This is an amazing accomplishment, but it does not show the *g*-factor.

Intelligent Brains

- Why are some people smarter than others? Does everyone have equal potential for learning all subjects? The answers must have something to do with the brain, but where in the brain is intelligence? We can ask this about *g* and about specific factors. Is one brain organized to be better at math and science, and another brain better at writing or creativity? If so, how did these brains get that way? What is the interplay between genetics and experience as they influence intelligence?

- In 1988, the first brain imaging study of intelligence was conducted using an imaging technology called positron emission tomography

(PET), which is a way to measure glucose use in the brain. This was done while people worked on a test of intelligence to see what brain areas "light up" during problem solving. Imaging technology has dramatically changed intelligence research.

- The parieto-frontal integration theory, or P-FIT, is a model that is based on a review of 37 imaging studies of intelligence. The P-FIT identifies a network of brain areas. The key areas are mostly in the parietal lobes—the sides toward the back of the brain—and in the frontal lobes. Intelligence may depend on how information flows around this network. If we could measure this information flow and how it may differ among people, we might devise a completely new way to measure intelligence from brain imaging.

- Many imaging studies show that intelligence test scores are related to measurements of brain structure and function. This virtually eliminates older concerns that intelligence test scores don't assess anything real or important.

- Can we increase intelligence? Today, the short answer is no—we can't increase intelligence. Some recent studies suggest that you can train your brain to increase your IQ, but the research on this subject is not at all settled. The longer answer is yes—we might be able to enhance intelligence in the near future.

- For example, research is already showing that drugs can focus attention during test taking, that electrical stimulation to the brain improves learning, and that manipulating genes improves learning. All neuroscience studies of intelligence will ultimately lead to attempts to increase both *g* and even specific factors.

Suggested Reading

Gottfredson, "Mainstream Science on Intelligence."

Hunt, *Human Intelligence*.

Jensen, *The* g *Factor*.

Neisser, Boodoo, and Bouchard, et al., "Intelligence."

Sternberg, Lautrey, and Lubart, *Models of Intelligence.*

Tammet, *Born on a Blue Day*.

Treffert, *Islands of Genius*.

Questions to Consider

What is the difference between IQ and general intelligence?

What is the difference between savant mental ability and the *g*-factor?

Assessing Intelligence

Lecture 2

In this lecture, you will learn about measuring intelligence, focusing on IQ testing. Measurement is required to do scientific research on intelligence. No single test may be a perfect measure of a single definition, but as research findings accumulate, both definition and measurement evolve, and our understanding of the complexities increases. This lecture will focus on two topics: the history of IQ tests and how they work—including the kinds of items found on the most widely used tests—and some of the issues surrounding what intelligence tests actually measure.

The History of IQ Tests

- Psychometrics is the measurement of psychological phenomena like intelligence—often with paper-and-pencil tests. Most intelligence testing is based on psychometric approaches that rely heavily on statistical methods, including the properties of the normal distribution curve. Many psychologists believe that IQ tests are one of the great achievements in psychology, although there is considerable controversy about them.

- In the early part of the 20th century, Alfred Binet and his collaborator Theodore Simon devised the first IQ test to identify children who mentally could not benefit from ordinary school instruction. The IQ test was born as an objective means for identifying low mental ability in children so that they could get special attention.

- The test constructed by Binet and Simon consisted of several subtests that sampled different mental abilities with an emphasis on tests of judgment because Binet felt that judgment was a key aspect of intelligence. He gave each test to many children and developed average scores for each age and sex. He then was able to say at what age level any individual child scored. This was called the child's mental age.

- A German psychologist named William Stern took the concept of mental age another step further. He divided mental age by chronological age. This resulted in an IQ score that was the ratio of a child's mental age (averaged across all of the subtests) divided by the child's chronological age. Multiplying this ratio by 100 avoided fractions.

- The point of these early tests was to find children who were not doing very well in school—relative to their peers—and get them special attention. The Binet-Simon test actually worked reasonably well for this purpose. However, one problem with the concept of mental age is that it is hard to assess after about age 16. As a result, the Binet-Simon test was not really useful or intended for adults.

- The IQ score is a measure of a child relative to his or her peers. Even today, newer IQ tests based on a different calculation show how an individual scores relative to his or her peers. IQ scores are not absolute measures of a quantity; an IQ point is not always the same in terms of a quantity of intelligence.

- Nevertheless, the Binet-Simon test was an important advance for assessing the abilities of children in an objective way. The Binet-Simon test was translated to English and redone at Stanford University in the 1920s by Louis Terman, and the test is now known as the Stanford-Binet test. Today, the Stanford-Binet test has been revised and updated many times. One key change is in the way IQ is calculated. Mental age is no longer used; IQ is now based on deviation scores.

- The Wechsler Adult Intelligence Scale (WAIS) was designed for adults, and it is the most widely used intelligence test today. The current version consists of a battery of 10 core subtests and another five supplemental subtests. Together, they sample a broad range of mental abilities. The WAIS uses deviation scores to calculate an overall IQ score.

- IQ scores are normally distributed in large populations, and so are subtest scores. The tests were developed so that this would be true—that is, items that proved not to be normally distributed were eliminated from the test.

- Each subtest has been taken by a large number of males and females of different ages. These are the norm groups. Each norm has an average score called the mean, and the spread of scores around the mean is measured by a statistic called the standard deviation.

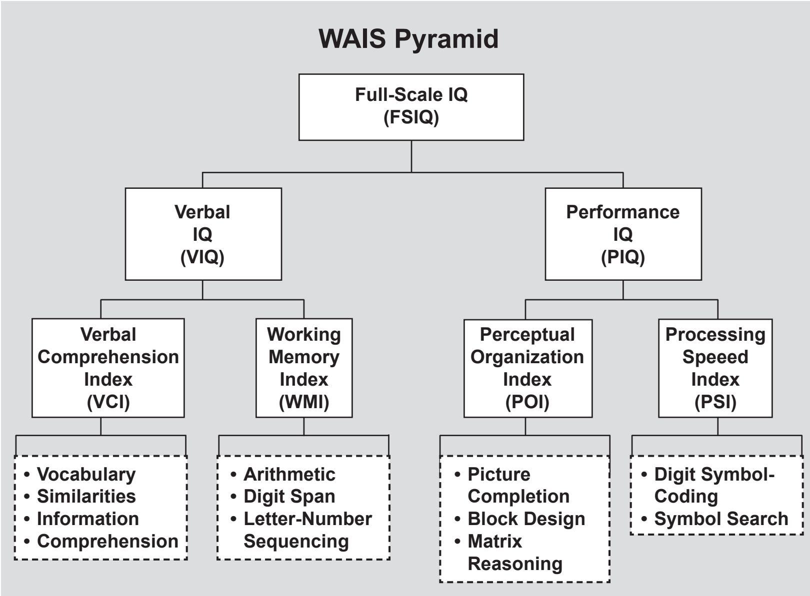
- The average deviation across all of the subtests is used to calculate the deviation IQ for the full battery. One standard deviation above the mean ranks the person higher than 84 percent of the norm group; one standard deviation IQ below the mean ranks the person at about the 16th percentile.

- The WAIS can be divided into specific factors other than the full-scale IQ score. The structure of the WAIS looks just like the pyramid structure of mental abilities from the last lecture. At the bottom are the individual subtests. They are grouped at the next highest level into factors of verbal comprehension, working memory, perceptual organization, and processing speed. These four specific factors are grouped into more general factors of verbal IQ and performance IQ, and these two broad factors have a common general factor defined by the total IQ score, called full-scale IQ, which is a good estimate of the *g*-factor.

Sample IQ Test Items

- Intelligence tests fall into two categories. The first is based on individual testing, in which one tester administers the test to one person at a time. This usually takes at least two hours and can take all day depending on how tests are given. Additionally, it can be quite expensive.

- The other category is based on group testing. One tester can give the test directions to a group and then let each person work simultaneously without interaction with the test administrator.



Depending on the group tests used, this can take less than an hour or all day. Group testing is more efficient and typically costs less.

- The WAIS is an individually administered test. One of its subtests is called General Information. Example questions include the following.
  - What is the capital of Italy?
  - What is the approximate population of India? (+/– 200 million)
  - Who were the Goths?
  - Who is pictured on the $100 bill?
  - What symbol is on the Canadian national flag?

- Another WAIS subtest is called Digit Span. The test administrator reads a series of digits, and when finished, you repeat the digits back in order. This test has two parts: In the first part, you repeat the digits in order; in the second part, you repeat the digits backward—in reverse order. The more digits you repeat, the higher your score. This test does not seem as vulnerable to bias as general information.

- Answering or not answering any one item, or doing poorly on any one subtest, does not mean that you are not smart; it's the total of all items that matter for general intelligence, and not all subtests are equally good indicators of *g*. The term *g*-loading refers to the amount of *g* represented in a test.

- The WAIS is really a battery of separate tests, and the combined scores (into one IQ number) estimate *g*. There are many other tests that also estimate *g*, including Raven's progressive matrices, analogies, and SATs.

- The Raven's test can be given in a group format and takes less than an hour. It's one of the best tests to estimate *g*. It's a nonverbal test of abstract reasoning. The underlying pattern or rule can be quite difficult to infer, but because of its simple administration, this test has been used in many research studies. Scores on this test can be converted to approximate WAIS IQ scores. Performance on a test like this seems fairly independent of education or even culture.

- Analogy tests also are very good estimators of *g*.
    - Wing is to bird as window is to _____ (house).
    - Helium is to balloon as yeast is to _____ (dough).
    - Monet is to art as Mozart is to _____ (music).

- Originally, the SAT was called the Scholastic Aptitude Test, then it was renamed the Scholastic Achievement Test, and now it's called the Scholastic Assessment Test. Achievement tests

measure what you have learned. Aptitude tests measure what you might learn, especially in a specific area. The SATs, especially the overall total score, are also a good estimator of *g* because the problems require reasoning. Like IQ scores, the meaning of SAT scores is based on percentiles. Both IQ scores and SAT scores are normally distributed.

- Part of the confusion is that achievement scores, aptitude scores, and intelligence scores are all related to each other. They are not independent. The *g*-factor is common to all tests of mental ability, and the *g*-factor is related to learning ability. Your performance on achievement tests is related to the general factor—just like IQ scores and aptitude test scores are related to *g*.

Issues with IQ Tests

- The main problem with the IQ score is that it is not a real ratio scale, which means that there is no true zero. IQ scores rank a person relative to other people, so a person with an IQ score of 140 is not really twice as smart as a person with a score of 70. For IQ, it's the percentile that counts.

- Intelligence test scores only estimate intelligence because we don't yet know how to measure intelligence as a quantity, like measuring liquid in liters or temperature in degrees. Whatever you think about intelligence tests and IQ scores, they do predict success in many aspects of everyday life, and IQ scores are related to brain characteristics. These relationships help establish the validity of intelligence tests.

- Possibly the most controversial topic in all of psychology is whether intelligence tests are biased against any groups. Test bias has been studied extensively for decades, and although test abuse certainly happens, most researchers find that intelligence tests are not inherently biased against any one group. This is not to say that factors like education and culture don't matter.

Suggested Reading

Gottfredson, "Mainstream Science on Intelligence."

Hunt, *Human Intelligence*.

Jensen, *Bias in Mental Testing*.

———, *Straight Talk about Mental Tests*.

———, *The* g *Factor*.

Johnson, Nijenhuis, and Bouchard, "Still Just 1 'g'."

Neisser, Boodoo, and Bouchard, et al., "Intelligence."

Sternberg, Lautrey, and Lubart, *Models of Intelligence.*

Questions to Consider

What do IQ tests measure, and what don't they measure?

Why aren't IQ points like liters of liquid or degrees of temperature?

General Intelligence in Everyday Life

Lecture 3

This lecture is based largely on the research of Linda Gottfredson, a sociologist at the University of Delaware who studies intelligence. In this lecture, you will be exposed to data that shows that general intelligence is related to many aspects of life—not just academics. In fact, some of the data may surprise you. First, this lecture will examine 10 areas of everyday life and briefly illustrate the importance of intelligence in each one. Then, it will introduce you to actual data about what *g* predicts and address whether any of the data have implications for public policy.

Intelligence in Everyday Life

- It is important to realize that *g* does not predict everything, but it predicts best wherever demands for general thinking skills are highest—that is, most *g*-loaded. The following are 10 life areas where *g* matters.
  1. School success: It's an old question as to whether some kids should get into the honors or advanced classes based only on intelligence test scores, but intelligence does matter when it comes to speed of learning, especially for advanced material.

  2. Income and managing money: A very cynical statement—"If you divided all of the money in the world equally among everyone, in six months, the same people would have it back"—could be a statement, even an extreme one, about the importance of intelligence for understanding money-management concepts.

  3. Prescriptions and medical instructions: Many medical directions are quite complex. Should doctors assume that all patients understand equally well? Drug information from the pharmacy tends to be written at a fairly high level, so lower-IQ people may have more misunderstandings and less effective compliance.

4. Accidents and health: Low IQ is associated with more accidents and shorter longevity. Misunderstanding of health and safety issues is more common.

5. Using computers and other digital devices: This requires some basic problem-solving skills.

6. Reading bus or train schedules: The iconic map of the London Underground rail system shows complex information in a relatively simple visual way, but this is the exception—not the rule.

7. Filling out employment or government forms: If you think you're smart, try filling out your own tax forms.

8. Vocational choice: Can you really be anything you want to be, irrespective of your IQ? This is a key issue about the extent to which intelligence is a limiting factor.

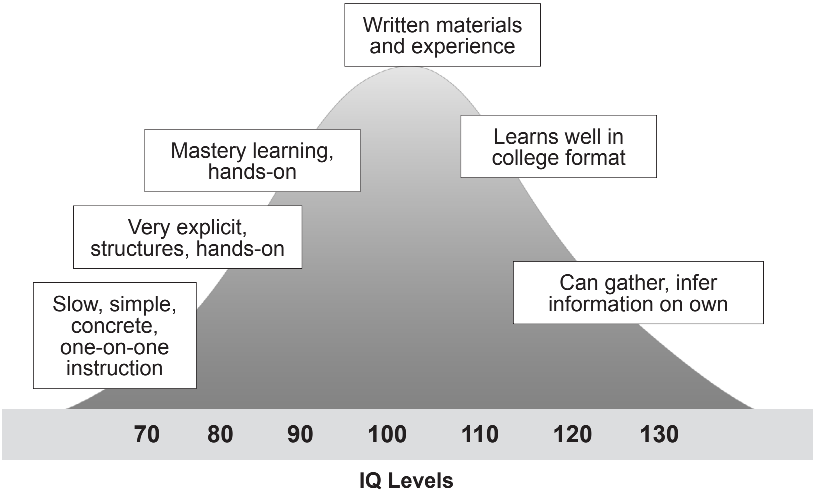
9. Job success: Which is more important: IQ or emotional intelligence? As jobs become more complex, IQ may be necessary, but not sufficient without the ability to get along with other people.

10. Basic life decisions: Watch a few episodes of the television show *Judge Judy*. Certainly not all of the cases involve people with lower intelligence, but you will see real examples of how poor reasoning and poor decision making create all kinds of life complexities and problems.

What Does *g* Predict?

- In the normal distribution of IQs, lower IQs, around 70, usually mean that learning is slow, simple, and requires concrete, step-by-step teaching with individual instruction. Learning complex material is often not possible. IQs around 80 to 90 still require very explicit, structured, individual instruction. When it comes to learning by written materials, IQs of at least 100 are usually required, and

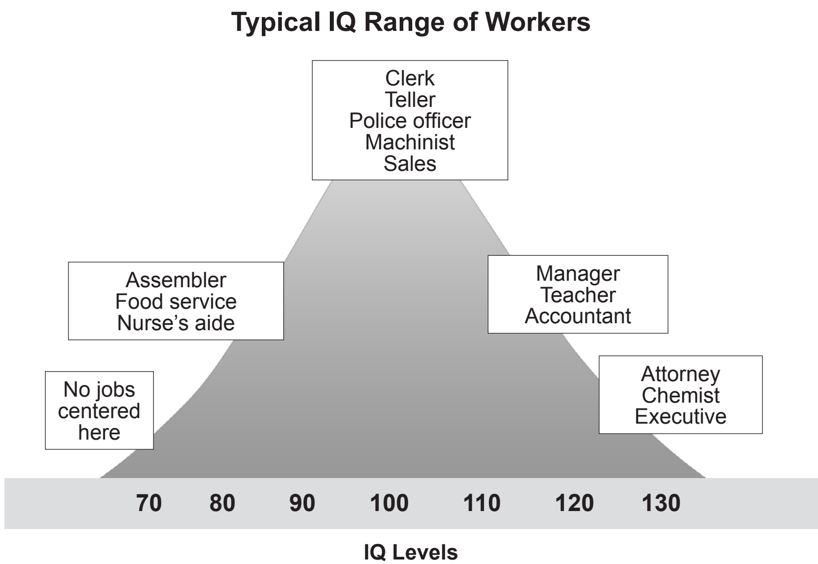
Typical Learning Needs by IQ Level



college-level learning usually works best at 115 and over. Higher IQs, over 130, usually mean more abstract, independent learning.

- According to scientific research, low IQs are associated with jobs that require a minimum of complex, independent reasoning. The jobs tend to follow specific routines, including assembling a simple product or being a nurse's aide. As IQ increases to around 100, we see more complex jobs, such as bank tellers and police officers, and as IQ increases to around 115, more complex jobs are possible, such as managers, teachers, and accountants. Professions like attorneys, chemists, and business executives usually require higher IQs to finish the advanced schooling that is required and to perform at a high level of complexity.

- These are general trends. There are always exceptions, which is why an IQ score by itself is not usually used to make an important decision. IQ is usually considered in the context of other information.



- Even having a discussion about the role of intelligence in job success becomes uncomfortable because it implies serious limitations on personal achievement, and we want to believe the ideal that, in this country, people can succeed at anything they choose to do if they work hard enough. A reasonable caveat is that this is true providing that they have the appropriate level of mental ability.

- According to research, IQ matters more for success in complex jobs than for success in less complex jobs. Complex job performance is largely dependent on *g*, but of course, there are other factors, including how well one deals with other people. This is the concept of emotional intelligence. In other words, intelligence alone is not the whole story for predicting success.

- Studies suggest that expertise in any area requires at least 10,000 hours of practice—that's 1,250 eight-hour days, or about 3.4 years. Studies of chess grandmasters suggest that the group average IQ is about 100. This suggests that becoming a grandmaster may depend

more on practice of a specific ability like spatial memory than on general intelligence. Grandmasters may actually have a savant-like spatial memory, but the idea of a chess grandmaster being a giant intellect is not necessarily correct.

- Another way to look at the role of thinking skills and everyday life is based on functional literacy data. Functional literacy is assessed by the complexity of everyday tasks that a person can complete. Intelligence helps us navigate the problems of everyday life. Functional literacy is a good indicator of intelligence, and from data on functional literacy, we know that many people have trouble with daily tasks that some people may take for granted.

IQ and Public Policy

- Should data inform or influence public policies? In a free and capitalist society, can lower-IQ individuals—in the bottom 15 percent, for example—expect government help (federal, state, or local) that is not needed by higher-IQ individuals? Is the half of the population with IQs under 100 a permanent drag on society? Some people may think so.

- *The Bell Curve*, written in 1994 by Richard Herrnstein and Charles Murray, is a controversial book that explores the role of intelligence in social policy. The main theme is that modern society increasingly requires and rewards people with the best reasoning skills—that is, high intelligence. Therefore, people in the bottom part of the normal distribution of IQ will be at a serious disadvantage for succeeding.

- This theme was detailed with over 900 pages of data and statistical analyses, but the part that aroused the most controversy was over one chapter that discussed racial IQ differences. This issue haunts all intelligence research.

- The issue surrounding *The Bell Curve* is whether public policy needs to recognize that people with low IQs need help navigating life—irrespective of race, background, or even why they might have low IQs. This is a fundamental issue today in politics,

although the role of IQ is hardly mentioned as explicitly as it was in *The Bell Curve*. Most researchers would agree that research data on intelligence can only inform policy decisions, but the goals of the policy need to be determined through democratic means.

- The most practical general lesson for public policy that comes from intelligence research is to reduce complexity. Some examples for reduced complexity in everyday life include directions for medication and prescriptions, forms of every kind (think taxes), bus and train schedules, instruction manuals, and assembly manuals.

- The data that show that *g* is a key factor in life success imply that intelligence is a limiting factor and that you can only be anything you want to be if you have the required level of intelligence. This goes against the implication that work ethic can always trump mental ability.

- Malcolm Gladwell's book *Outliers* emphasizes the role of luck. The following are four points about this view.
    - Whereas *The Bell Curve* documented the basic role intelligence plays in everyday life success, Malcolm Gladwell expresses a point of view that luck plays an even bigger role than intelligence.

    - His examples are mostly anecdotal. It's hard to prove whether luck or intelligence is more important for life success. Research on luck is hard to conceptualize. This is an argument that cannot be resolved by research.

    - Perhaps, Gladwell would agree that a person can be anything they wish to be given that they work hard and are lucky.

    - People who focus on intelligence typically do not downplay the role of luck; people who focus on luck should not downplay the role of intelligence.

- Intelligence predicts navigation of complexity in everyday life. Research so far suggests that IQ represents the single most useful tool in the tool kit of human mental abilities. Recognizing that people with lower IQs have the most difficulty in navigating modern life is something to consider in all aspects of designing society.

Suggested Reading

Gottfredson, "Mainstream Science on Intelligence."

———, "Why *g* Matters."

Hunt, *Human Intelligence*.

Jensen, *The* g *Factor*.

Neisser, Boodoo, and Bouchard, et al., "Intelligence."

Sternberg, Lautrey, and Lubart, *Models of Intelligence.*

Questions to Consider

What must it be like every day to have an IQ of 80? How about 180?

What does intelligence have to do with learning and job skills?

To *g* or Not to *g*—Is That the Question?

Lecture 4

This lecture will explore some alternative concepts that many people find more appealing than the *g* concept, but this lecture will also explain why they might not be. You will learn more details about the pyramid structure of mental abilities, including a statistical method called factor analysis, which allows us to find the groups of subtests that are most related to each other. This lecture will also discuss Sternberg's theory of practical intelligence and Gardner's theory of multiple intelligences. Finally, you will learn about the influence of culture and social context on concepts of intelligence.

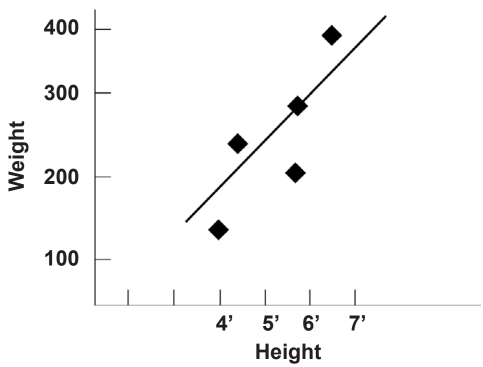
Factor Analysis

- Most theories about factors of intelligence start with the empirical observation that all tests of mental abilities are positively correlated with each other. This is called the positive manifold, and it was first described by Charles Spearman, who worked out statistical procedures for identifying the relationships among tests based on their correlations with one another. The basic method is called factor analysis.

- Let's say that we measure height and weight in many people. We can graph each person by locating the height and weight as a single point, with height ranges on the x-axis and weight ranges on the y-axis. When we add points on the graph for each person, we begin to see an association: Taller people tend to weigh more. Height actually predicts weight, although not perfectly, so if we know that a person is 6.5 feet tall, we can predict that they will weigh around 280 pounds.

- If height and weight were perfectly related, the points would all fall on a straight line, and we could predict one from the other without error. A perfect correlation has a value of 1 if a high value on one variable goes with a high value on the other variable.

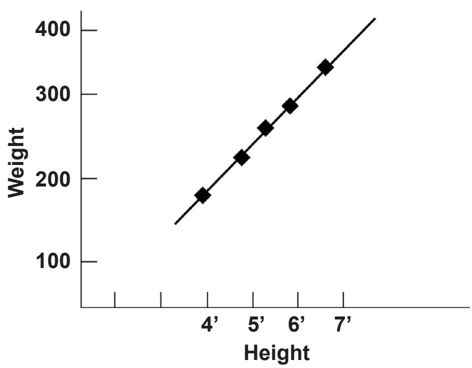
Correlation



A perfect negative correlation is where a low value on one variable predicts a high value on the other. A perfect negative correlation has a value of –1.

- Correlations between two variables are calculated based on how much each point deviates from the perfect line, and they always fall between +1 and –1. The higher the correlation—positive or negative—the stronger the relationship, and the better one variable predicts the other.

Perfect Correlation



- Factor analysis is based on the pattern of correlations among several variables; in this case, we are interested in the correlations among different tests of mental abilities. The point of factor analysis is to identify what tests go with other tests—based not on content, but rather, on correlations of scores irrespective of content. The set of tests that go with each other define a factor because they have something in common that causes the correlation. Studies in this field typically apply factor analysis to data sets where hundreds or thousands of people have completed dozens of tests.

Models Based on Factor Analysis

- Louis Thurstone proposed a model of seven primary abilities that he claimed were independent of each other—that is, they were not correlated to each other, and there was no common *g*-factor. Thurstone's seven abilities are as follows.
    - Spatial ability: measured by tests that require mental rotation of pictures and objects.
    - Perceptual speed: measured by tests of finding small differences in pictures as quickly as possible.
    - Number facility: measured by tests of computation.
    - Verbal comprehension: measured by tests of vocabulary.
    - Word fluency: measured by tests that require generating as many words as possible for a given category within a time limit.
    - Memory: tested by recall for digits and objects.
    - Inductive reasoning: measured by tests of analogies and logic.
- Thurstone's model was not supported by subsequent research. The original research by Thurstone was flawed because the samples he used did not include individuals across the full range of possible scores—a statistical problem called restricted range that influences

the calculation of correlations. When researchers corrected this problem, they found that tests of the Thurstone primary abilities, in fact, are correlated to each other and that there is a *g*-factor.

- Since Spearman and Thurstone and other pioneers of factor analysis, we now have hundreds of factor-analysis studies of intelligence on hundreds of mental tests completed by tens of thousands of people. There always is a *g*-factor, and *g*-factors derived from different test batteries correlate nearly perfectly with each other—as long as each battery has a sufficient number of tests that sample a broad range of mental abilities and the tests are given to people sampled from the broad range of ability. This fact is strong evidence for *g*.

- Raymond Cattell and his student John Horn proposed a model with two principal factors: fluid intelligence and crystallized intelligence. This distinction is widely recognized as an important evolution in the definition of intelligence. Both are related, so they are not in conflict with the *g*-factor. They represent factors just below *g* in the pyramid structure of mental abilities.

- Fluid intelligence refers to reasoning ability—both inductive and deductive—to solve novel problems, often using facts and information you already know. In many studies, fluid intelligence and the *g*-factor are correlated almost perfectly. Crystallized intelligence refers to what you know and the ability to learn facts and absorb information.

- Crystallized intelligence is fairly stable over a life span, but fluid intelligence decreases with age. The likely explanation for these differences may lie in how age affects some parts of the brain more than others. Fluid intelligence peaks around age 15 and slowly declines. Crystallized intelligence steadily increases with age.

- Differences among factor models of intelligence and many other models have given some critics the idea that *g* is merely a statistical artifact of the factor analysis method. This criticism depends on

very technical aspects of how factors are computed. The artifact view has been examined extensively, and it has never really held up.

Sternberg's Theory of Practical Intelligence

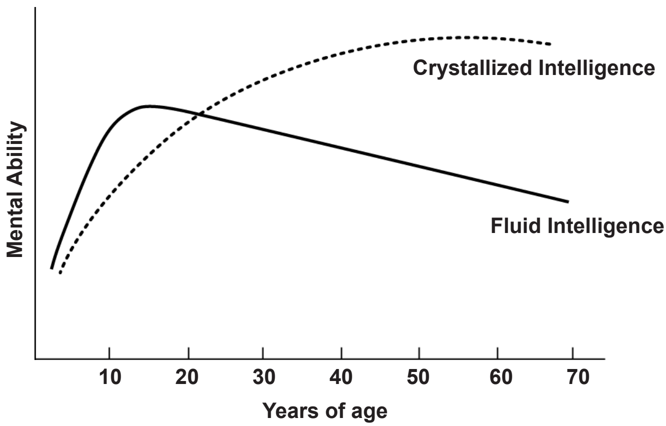
- Robert Sternberg is one of the most prolific intelligence researchers. Sternberg proposed a theory of practical intelligence—called the triarchic model—based on three kinds of intelligence: analytic (reasoning skills; most intelligence tests measure this kind of intelligence), creative (non-*g*-related ability to originate new ideas; it's difficult to have psychometric tests to measure this), and practical (the emphasis in Sternberg's model; it's common sense, and it may include emotional intelligence). High *g* individuals can lack practical intelligence, and as a result, do unintelligent things.

- These three components were not derived by traditional factor analysis; they were based on theoretical distinctions, but Sternberg has developed tests for all three. Sternberg recognizes that *g* exists. His main argument is that these three components are more important than *g*, and that, unlike *g*, they can be taught. This, of course, is a less limiting view than that of a fixed *g* and, therefore, quite appealing to educators.

- Sternberg has actually instituted educational innovations in some school settings based on his model. He and his colleagues have published a series of research papers testing his central ideas in a broad range of studies—some with generally positive results. It's an extremely ambitious and impressive program of innovation and testing.

- The problem is that some independent analyses find that any predictive value the Sternberg tests have, can, in fact, can be explained more simply by *g*. Like many issues in psychology, the bottom line is not yet clear as to whether the Sternberg model improves on or expands the basic *g* concept. It's also important to keep in mind that Sternberg's model is relatively new compared to over 100 years of research on *g*, so we'll await more data.

Fluid Intelligence and Crystallized Intelligence



Gardner's Theory of Multiple Intelligences

- For Howard Gardner, the *g*-factor is unnecessary. Gardner proposed a model of independent multiple intelligences. The following are the basic intelligences, although the list has changed from time to time.
    - Linguistic intelligence: reading, writing, and all language skills.
    - Logico-mathematical intelligence: solving math problems and logical reasoning.
    - Spatial intelligence: getting places; packing a suitcase.
    - Musical intelligence: includes singing, composing, and playing an instrument.
    - Bodily/kinesthetic intelligence: dancing and athletics.
    - Interpersonal intelligence: understanding other people.
    - Intrapersonal intelligence: understanding oneself.
    - Naturalist intelligence: understanding patterns in the natural world.

- Even though the idea of multiple intelligences is similar to Thurstone's model of primary mental abilities, the basis of Gardner's model is not empirical—there are no factor analyses or any other quantitative approach.

- Gardner has not developed any tests of these intelligences. Other researchers have developed tests of the multiple intelligences defined by Gardner, and the tests are correlated with each other—that is, there is a *g*-factor.

- Despite the fact that there is little empirical research evidence to support the concept of independent multiple intelligences, it is possibly the most popular model of intelligence outside the research world, especially among parents and educators, for three key reasons: It appeals to the ideal that everyone has some special ability, it doesn't recognize the limitations implied by *g*, and it's based on observations and anecdotes easy to understand rather than on complicated statistics.

Intelligence and Social Context

- Richard Nisbett is a prominent advocate for the importance of social and cultural approaches to intelligence, and he has written on it extensively and clearly. The following is a short summary of three key points of Nisbett's view about intelligence.
    - Genes don't count for much.

    - Social context determines IQ—not the other way around.

    - Schools and education make a big difference in IQ—not the other way around.

- Research on social and cultural factors often show influences on test scores. The controversy is really about what such influences tell us regarding how intelligence develops, and the key question is how malleable intelligence may be if social and cultural factors are manipulated. Another consideration is whether intelligence is malleable if the underlying neurobiology of the brain is manipulated.

Suggested Reading

Gardner, *Frames of Mind*

Gottfredson, "Dissecting Practical Intelligence Theory."

———, "Mainstream Science on Intelligence."

Hunt, *Human Intelligence*.

Jensen, *The* g *Factor*.

Neisser, Boodoo, and Bouchard, et al., "Intelligence."

Nisbett, *Intelligence and How to Get It*.

Sternberg, *Successful Intelligence*.

Sternberg, Lautrey, and Lubart, *Models of Intelligence.*

Questions to Consider

Is common sense the same as intelligence?

Is the *g*-factor really the most important aspect of intelligence?

Intelligence and Genius over the Life Span

Lecture 5

In this lecture, you will learn about a very select group of individuals with test scores in the upper end of the normal distribution and follow them from childhood into old age. This lecture will address three classic research studies. Each one starts with children and tests their mental abilities and life successes at various intervals over decades. These three classic studies provide compelling data that a single psychometric test score at an early age predicts many aspects of later life, including professional success, healthy aging, and even mortality.

The Terman Study

- In the 1920s, Lewis Terman at Stanford University initiated a straightforward study that began by testing many school children with the Standford-Binet test. Children with very high IQs were selected and then studied extensively for decades.

- Terman's study had two goals: to find the traits that characterized high-IQ children and to see what kind of adults they would become. According to Terman, the common stereotype of intelligent children was simply "early ripe, early rot." This similarly applied to child prodigies who were thought to be abnormal, poorly adjusted, prone to burnout, and even psychotic. These beliefs can be viewed as a kind of social justice theory—meaning that if you're really great in your mental ability, then you should be bad in all other abilities to balance things out.

- In 1920 to 1921, 1,470 children with IQs between 135 and 196 (top one percent) were selected from over 250,000 in California public schools; they were retested and interviewed every seven years. Their average IQ was about 150, and 80 children had IQs over 170. These were in the top 0.1 percent. This group became known unofficially as the termites.

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The study of children's IQ levels can be controversial if the researcher intervenes in the lives of the children.

- They completed extensive medical tests, physical measurements, achievement tests, character and interest tests, and trait ratings, and both parents and teachers supplied additional information. A control group with average IQ scores was also tested. The results of Terman's study were published over time in five volumes. The data was quite extensive, but the following is a summary of key findings about the lives of the termites.
    - Overall, they completely refute the stereotypes both for children and adults. The negative, nerdy attributes were basically unfounded; they actually were physically quite robust and more physically and emotionally mature than their age-mates.

    - On average, the termites were happier and better adjusted than the controls over the course of the study.

    - Although they had their share of life problems, follow-up studies showed considerable achievement with respect to publishing books, scientific papers, short stories and poems,

musical compositions, television and movie scripts, and patents—just what you'd expect from a very high-IQ group.

  - However, further follow-up indicated that high IQ alone did not necessarily predict life success. Motivation was also important, and Terman believed that while genes played an important role in high IQ, he also believed that exceptional ability required exceptional education to maximize a student's potential. This may not sound so radical, but even today there is a debate about whether any education resources at all should be allocated to the most gifted students to develop their high ability.

  - Terman's project also demonstrated the predictive validity of the IQ score—that is, one IQ score in childhood can identify individuals who will excel in later life.

- Like all studies, however, there were some major flaws. Terman intervened in the lives of these "subjects" and helped them with letters of reference for college and for employment. Strong sex bias in education and employment resulted in female termites mostly becoming housewives, so good male-female comparisons were not possible. Similarly, there is no data about minorities. However, it is not likely that these problems invalidate the main findings; overall, the level of success and the achievement of these very high-IQ individuals stand on their own.

The Scottish Mental Survey

- All children born in Scotland in 1921 and in 1936 completed intelligence testing at age 11 and were retested in old age. This study included virtually all children in the country on a test of general intelligence rather than identifying samples of very high scorers. The total number of children in the study was about 160,000.

- In the 1930s, one of the reasons that the Scottish government sponsored this study was a concern that the national IQ level was decreasing because less intelligent people were having larger

families. Actually, from the original testing, there was a clear trend that children from larger families had lower IQ scores.

- There are many possible explanations, including that higher-IQ parents have fewer children or that very large families were even poorer than smaller families, so opportunities for education were even less available. The trend itself does not identify the causes.

- At the time this study began, there was considerable debate around the world about national intelligence and eugenics. This clearly had very dark and evil consequences in Germany. It's one of the reasons intelligence testing became a negative topic in academia following World War II.

- Another reason for using intelligence tests in some countries was the desire to open opportunities for better schooling to all social classes by using test scores as an objective evaluation. This actually happened in the United Kingdom after the war, and this motivation was important in the development and use of the SAT in the United States.

- The Scottish survey was over after the second round of testing in 1936. It only became a longitudinal follow-up study largely by accident. Today, a team of researchers directed by Ian Deary at the University of Edinburgh is using this database and follow-up evaluations to study the impact of intelligence on aging.

- Dr. Deary discovered that IQ scores were fairly stable over time by showing that scores at age 11 strongly correlated to scores at age 80. In addition, individuals with higher intelligence scores at age 11 lived longer than their classmates with lower scores.

- Why should IQ be related to longevity? There are many possible explanations. Before age 11, several factors—both genetic and environmental—may influence IQ, and then higher IQ leads to healthier environments and behaviors and to a possibly better understanding of physician instructions. These, in turn, influence

age at death. Because the United Kingdom has universal healthcare, differential rates of insurance coverage do not influence these data.

The Johns Hopkins Study

- The Study of Mathematically Precocious Youth at Johns Hopkins was another ambitious longitudinal project initiated by Julian Stanley in 1971. Dr. Stanley repeated Terman's approach, but instead of IQ scores, he used extremely high SAT math scores obtained by junior high school students aged 11 to 13 in special testing sessions called talent searches.

- Instead of general intelligence, Stanley focused on a very specific mental ability. This project also had two major goals: identify precocious students early and foster their special talent. The first talent search was in 1972. For that search, junior high school students in the Baltimore, Maryland, area had to be nominated by their math teachers to participate. In that first search, 396 seventh- and eighth-grade students took the SAT-M.

- Among other results of that first talent search, 22 of 396 students scored at least 660—higher than the average Hopkins freshman at the time. In addition, all of these 22 students were boys; none of the 173 girls scored over 600. These ratios have improved considerably over the years, but at the time, this huge disparity was shocking.

- The early data analyses confirmed Terman's results with respect to stereotype about the 22 boys who scored higher than Hopkins freshmen. These mathematically precocious students were more physically and emotionally mature than their age-mates. On average, they scored more like college students than their age-mates on personality tests.

- Stanley believed that enriched classes were not as productive as actual college classes, so he helped many of these very talented students go to college early. Like the termites, many went on to have successful and very productive careers.

- The original talent searches have evolved dramatically and now include many programs for enrichment in addition to early college admission, including summer camps that emphasize math and science experiences.

- There are now detailed follow-up studies of thousands of the students who participated in several of the original searches. Follow-up results show that many of these mathematically precocious children, as determined by a single test score when they were in their early teens, became very successful in terms of occupational and life success.

- The longitudinal study of the original talent-search participants is continuing with a 50-year follow-up planned by researchers Camilla Benbow and David Lubinski at Vanderbilt University.

- Today, talent searches and enrichment programs are still going on in many states modeled after Dr. Stanley's program and the ones later sponsored by the Johns Hopkins Center for Talented Youth. Over three million students have been tested, and hundreds of thousands have participated in special academic programs. In fact, this kind of search is now global, with the widespread recognition that finding and nurturing this kind of precocious mental ability is good for the students—and good for society.

Suggested Reading

Batty, Deary, and Gottfredson, "Premorbid (Early Life) IQ and Later Mortality Risk."

Gottfredson, "Mainstream Science on Intelligence."

Hunt, *Human Intelligence*.

Jensen, *The* g *Factor*.

Neisser, Boodoo, and Bouchard, et al., "Intelligence."

Stanley, Keating, and Fox, *Mathematical Talent*.

Sternberg, Lautrey, and Lubart, *Models of Intelligence.*

Terman, *Genetic Studies of Genius*.

Questions to Consider

Are nerds really better looking and stronger?

Can a single test score in childhood predict adult genius?

Early Childhood Experience and Intelligence

Lecture 6

In this lecture, you will learn how genes and environment influence each other by examining research on early childhood education and on other environmental factors, including prenatal effects, family factors, diet, and poison. There is still no strong evidence that tells us that intelligence can be increased by manipulating the early education environment—although things like lead poisoning might decrease intelligence. However, any environmental effect on intelligence, even ones due to education, must work through biological mechanisms to affect the brain. The same is true for all genetic effects because genes express themselves through biology.

Compensatory Education in the 1960s

- In the 1960s, when the war on poverty was declared during the Johnson administration, early childhood education was seen as key to overcoming the educational disadvantages of poverty. Children from poor communities often did not have preschool home situations that encouraged reading, counting, and other basics of learning to prepare for kindergarten. Moreover, the school systems in poor neighborhoods typically lacked basic educational resources, including outdated textbooks, limited libraries, and overburdened teachers.

- Partly a response to the civil rights movement and part of the war on poverty, compensatory education programs were initiated by the federal government. A key goal was to minimize or eliminate any effects of poverty on cognitive development as assessed by performance on achievement and intelligence tests. The main assumption, especially by educators and psychologists, was that poverty factors were responsible for most, if not all, of any cognitive disadvantages or gaps among racial or economic groups.

- In 1969, an educational psychologist from the University of California, Berkeley, named Arthur Jensen wrote a detailed article

that evaluated this assumption. The article was published in the *Harvard Educational Review* and was titled "How much can we boost IQ and scholastic achievement?"

- The article began with a now-famous sentence: "Compensatory education has been tried, and it apparently has failed." This article is possibly the most infamous and controversial article in the history of psychology, and it has had a profound effect on virtually all intelligence research to this day.

- In his article, Jensen came to the controversial conclusion that IQ and achievement were not increased by early childhood education. With regard to compensatory education, the following three key points can be garnered from the article.
  - Achievement and intelligence are not the same thing (even though tests of both are highly correlated to each other).

  - Compensatory education can influence factors of achievement—including motivation, self-confidence, and study habits—but there was scant evidence that it boosts intelligence. Any early gains disappeared after a few months or years.

  - Genes affected intelligence more than achievement, and this was why compensatory education had such little effect.

- Whereas today there is powerful scientific evidence and wide public acceptance of the idea that genes affect behavior, mental illness, and things like personality and intelligence, this was not the case in the late 1960s. In those days, anything genetic was regarded as deterministic and unchangeable. Today, we know that gene expression is dependent on many factors, and that's where epigenetics comes in—your genes are not your destiny.

- When Jensen expressed the view that intelligence was not amenable to change because improved education did not seem to have a measureable effect, he struck at the heart of conventional wisdom

and at the political goal of leveling the educational playing field. The following are four main criticisms of Jensen's views.

- He overemphasized the role of genes given the evidence at that time.

- He underestimated the potential of compensatory education: Even if the early studies failed—and even Jensen's critics acknowledge that the early results were not impressive—more intense compensatory efforts would be necessary, so it was too early to conclude that compensatory education could never work.

- He overstated the evidence that intelligence was stable over the life span.

- He undermined hope for eliminating the "achievement gap" between white students and minority students.

- Was Jensen wrong in concluding that compensatory education did not increase intelligence, as was hoped? Although there is good evidence that intelligence is fairly stable over a person's lifetime, new data challenges this view, and genes clearly play a powerful role in intelligence. Jensen was correct about these points.

- More recent efforts to increase achievement with compensatory education have been somewhat more successful than the early studies Jensen reviewed, but there is still no strong evidence of large, lasting gains for intelligence due to educational interventions. Surprisingly, the education achievement gap between white students and other students also remains about the same over the last 40 years, as Jensen predicted.

Early Childhood Education in the 21st Century

- Literature reviews in 1988 and 2010 looked at recent studies that attempted to raise intelligence with early education programs for at-risk children. The three basic findings are as follows. (In sum,

40 years of new data haven't really changed the results about improving IQ.)

- ○ The programs varied in their intensity.
- ○ Any IQ gains tended to fade over time.
- ○ More intense and expensive programs had better results that lasted longer, but intelligence gains were still quite small.

- The most intensive early education program completed to date is called the Abecedarian project, and its lead investigator is Craig Ramey. This was quite an ambitious and expensive project. It started as educational intervention in the first months of life and continued evaluation until young adulthood. There were important results for intelligence and for future achievement.

- IQ scores decreased over time for both the early education group and the control group, but the early education group maintained a five-point advantage over time. The intervention started before age five, so it's not clear whether the five-point advantage at age five resulted from the intervention or whether the two groups did not start out with equivalent mean scores.

- It's also odd that decreases occurred over time, but there are two main considerations: IQ tests for five year olds are not as reliable as those for older children and young adults, and brain maturation related to intelligence may not begin until later in childhood.

- Regardless, the data do not make a compelling argument that this early, intense educational intervention in disadvantaged children did much for improving IQ. However, results for future achievement were better. The early education group showed some lasting improvements for a number of behaviors, including better study skills and better social interactions, fewer behavioral problems, and increased entry to college.

- The general conclusion after more than 40 years of research is that there still is no strong evidence of large, lasting improvements in intelligence, as measured by tests, due to early education for at-risk children, but there are other benefits related to achievement. Jensen's conclusions were consistent with these results.

Intelligence and the Physical Environment

- Physical environmental factors that may affect intelligence include prenatal and infant health, diet, toxins, the home environment, socioeconomic status, culture, family size, and birth order. There are three general problems that you should keep in mind when discussing research on whether these factors influence IQ.

- How do researchers design studies comparing effects of two environments when we have no comprehensive measure of environmental similarity? Environments are really quite complex and have many possible factors that change over time.

- People are not randomly assigned to environments. To some degree, people select their environments. Even children decide to play with other children they like, or they may even prefer to play alone. This self-selection may be partly genetic. Personality traits like shyness or extroversion may have a genetic component; this complicates identifying "environmental" factors.

- Few environmental factors are independent of other factors. Socioeconomic status, for example, is related to lower income, poorer nutrition, and fewer educational opportunities, and it is also related to genetics because people tend to marry within their own social class. These related interactions are quite difficult to control in experiments.

- Toxin exposure in early life can affect brain development; fetal alcohol syndrome, pesticides, and lead poisoning all show definite relationships with lower IQ scores to varying degrees.

Children who are raised in environments that do not support their learning might prove to be intellectually disadvantaged.

- Some studies show about a three-point IQ difference in favor of children who were breast-fed, and a study published in 2012 claimed to show that children who ate the most junk food at three years of age had lower IQs at age 8.5. Chronic malnutrition may affect attention/memory but can be reversed when diet normalizes. Overall, it's actually difficult to prove that general nutrition affects IQ very much.

- In general, the better the home environment, the better children do on tests, but the effects are small and do not last beyond early childhood. These studies tend to be confounded with parents' IQs (for example, number of books in the home). Interestingly, the number of words spoken at home is related to language and may be related to verbal IQ.

- In terms of birth order, in two-child families, there is no apparent IQ difference between the first- and second-born child. There is also no birth order difference in IQ in three-child families. The data

for four-child families seems to be more variable, but none of the differences are statistically significant. Although birth order has no appreciable effect, the average child's IQ for one-child families is higher than for larger families.

- In terms of family size, mothers with more children have lower IQs than mothers with fewer children. On average, mothers with more children are in the 24th percentile whereas mothers with only one child are in the 44th percentile.

- What we conclude from data like these on family size or from birth order isn't clear. These examples actually show how difficult it is to identify the interplay between intelligence and environmental factors, even when we have clearly defined variables like family size and birth order.

Suggested Reading

Gottfredson, "Mainstream Science on Intelligence."

Hunt, *Human Intelligence*.

Jensen, "How Much Can We Boost IQ and Scholastic Achievement?"

———, *The* g *Factor*.

Kuhl, "Early Language Learning and Literacy."

Kuhl, Tsao, and Liu, "Foreign-Language Experience in Infancy."

Neisser, Boodoo, and Bouchard, et al., "Intelligence."

Sternberg, Lautrey, and Lubart, *Models of Intelligence.*

Tsao, Liu, and Kuhl, "Speech Perception in Infancy Predicts Language Development."

Questions to Consider

What specific environmental factors in childhood influence IQ scores?

Why talk to infants if they can’t talk back?

Genes and Intelligence

Lecture 7

Consistent evidence for major genetic influences on intelligence differences comes from around the world and is based largely on powerful twin and adoption research designs. In this lecture, you will learn about twin data, adoption data, the search for specific genes, and gene-environment interactions in the context of the emerging field of epigenetics. In addition to being introduced to some historical data, you will be exposed to some of the newest data about brain genes and intelligence.

Twin and Adoption Studies

- Even before we had the first concept of genes—thanks to Gregor Mendel and his peas—it was easily observed that many traits, including intelligence, seemed to run in families. Early researchers used two simple strategies to determine whether any trait had a genetic component or not. They looked at twins and at adoptees.

- Because monozygotic twins—that is, identical twins—have 100 percent of their genes in common, any trait that was found in both twins was thought to have a genetic component. The more similar the twin pair, the stronger the effect of genes.

- Of course, identical twins also share both the prenatal and the postnatal environment, so the fact that identical twins may have quite similar intelligence test scores did not rule out the notion that the similarity was due to having similar environments.

- This problem was easily addressed by comparing the similarity of a trait between pairs of identical twins, who have 100 percent of their genes in common, to pairs of fraternal twins—that is, dizygotic twins—who share only 50 percent of their genes. Any similarities should not be as strong in the fraternal twins as they are in the identical twins, and many twin studies show this.

- Adoption studies can separate genetic and environmental influence, but often biological and adoptive environments are similar. Nonetheless, adoption research designs can be powerful in establishing whether genes are involved in a trait or not.

- There are a number of adoption studies of intelligence. They vary considerably regarding the ages at which tests are given and the exact tests and sample sizes used, but they typically show much higher correlations between the adopted child's IQ and the biological parent's IQ than between the IQ of the adopted child and the IQ of the adoptive parents. This is consistent with a genetic component to intelligence.

- An even more powerful design combines adoption and twins. It involves studying identical twins who were adopted from their biological parents in early life and raised separately in different families—often, one twin does not even know of the existence of the other.

- The first major studies of intelligence in identical twins reared apart were done in the early 20th century in Britain by Sir Cyril Burt, who gave intelligence tests to pairs of identical twins who had been reared apart. He correlated the scores for each pair and found a correlation in the identical twins reared apart of 0.771, suggesting a strong genetic component to intelligence. This correlation was nearly as high as the correlation for identical twins reared together in the same household.

- Subsequent twin studies done by different investigators around the world with large samples arrive at an average value for the correlation of intelligence scores among identical twins raised apart of 0.75. The average value for identical twins raised together is about 0.86. These values compare to the fraternal twin data that show average correlations for intelligence of about 0.60.

- Compelling data from independent researchers are completely consistent with Burt's analyses and his basic conclusion that genes

play an important role in intelligence. Today, there are very few critics left who completely dispute that genes play any role at all in intelligence, but there are some.

- The most famous modern study of intelligence in twins comes from the Minnesota study of monozygotic twins that were reared apart. Researchers at the University of Minnesota, led by Thomas Bouchard, found 139 identical twin pairs that were reared apart. This took 21 years (from 1979 to 2000) and included twins from around the world.

- All of the twins completed an elaborate battery of tests at the University of Minnesota for about 50 hours over a week. This included tests of intelligence, personality, attitudes, values, and many physical characteristics.

- Genetic components were found for several personality traits, like extroversion, and even for some attitudes and values. Some twins who had had no contact with each other until they were reunited in Minnesota had married women with the same names, drank the same beer, and even used the same brand of toothpaste. Identical twins reared apart in this study were quite similar on many things, especially on intelligence scores.

- In the Minnesota study, heritability for *g* was estimated at 0.70, or 70 percent—similar to the worldwide average of 0.75. Often, you may hear that research like this shows a 50-50 spilt between genes and environment. There is variability among studies, and there's an interesting factor that accounts for much of this variability: the age when twins are tested. In fact, the genetic influence on intelligence increases with age.

- There is data that indicates that the heritability of intelligence is stronger in families with high socioeconomic status and weaker in families with low socioeconomic status. This is an important observation that underscores the difficulties in assessing gene-environment interactions.

Shared and Nonshared Factos

- A shared environment is what it sounds like: Twins or siblings grow up in the same family, live in the same neighborhood, and go to the same schools; there are many shared general experiences that may influence intelligence. However, of course, there are also many experiences unique to each person, including different friends, different classes, and different teachers. These unique influences are the nonshared environment.

- Shared and nonshared environmental influences can be distinguished and estimated statistically by comparing similarities among intelligence scores for identical twins, fraternal twins, and siblings—reared together and reared apart.

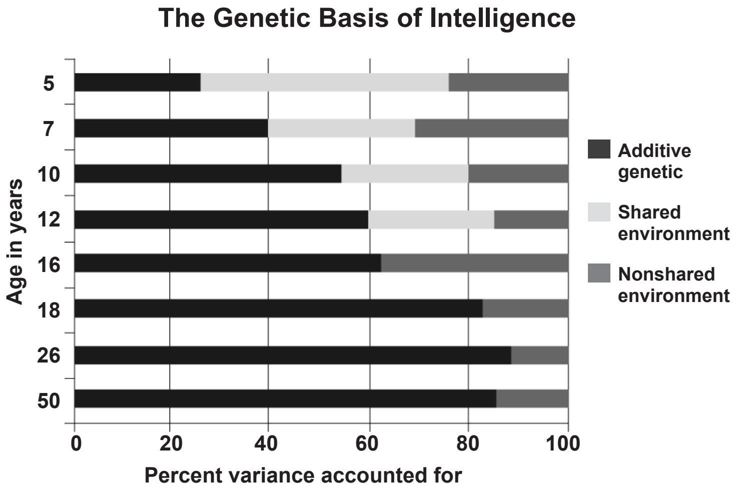
- Research shows that the influence of both shared and nonshared environments are fairly stable with a trend to decease with age, but the influence of shared environment decreases to about zero in adulthood. These findings are difficult to explain if you are convinced that genes are unimportant influences on intelligence. They also give pause to the idea that enriching childhood family experiences have a lasting effect on adult intelligence.

- Statistically, genetic, shared, and nonshared effects on intelligence can be estimated and added together to account for 100 percent of individual differences in intelligence.

Intelligence Genes and the Brain

- Overall, the case for genetic influences on intelligence is overwhelming. Because genes always work through biology, one implication is that there is a biological basis to intelligence, and this brings the study of intelligence into the realm of neuroscience. If genes are so important, then where are the intelligence genes? The simple answer is that we don't know—at least not yet. However, epigenetics complicates the story.

- Genes turn on and genes turn off throughout the life cycle. What controls genes turning on and off? Is this where environmental



factors, especially in early childhood, get their influence? The search for specific intelligence genes has been underway for some time, but without much success. Intelligence genes have been missing—that is, until recently.

- The newest studies show that intelligence and brain structure have genes in common. A very large study—an international collaborative effort—combined genetic and brain imaging techniques and was reported in 2009. It imaged white matter fibers in the brains of twins and determined genetic and environmental influences on white matter networks in the brain (communication among brain areas is based on white matter fibers).

- This study showed that in each major lobe of the brain—both for the right and left hemispheres—genetic influence on white matter is quite strong and nonshared environment has some influence, especially in the frontal lobe, but shared environment has virtually no influence on white matter.

- These researchers also correlated the similarity of IQ scores in the twins with the white matter. Then, they determined overlap between

where white matter was most influenced by genes and where IQ was most correlated to white matter.

- This example of combining DNA analysis, brain imaging, and IQ scores shows how far we are advancing beyond the old arguments about whether genes are important for intelligence and even whether intelligence can be studied scientifically. Genes not only play a role in intelligence, but the new data also show common genes for intelligence and specific brain features like white matter.

- A number of research groups around the world are using advanced genetic techniques to identify specific genes for intelligence. This includes using DNA sequencing machines to compare high and average IQ people to identify genes that are more frequent in the high group. Although this is a daunting challenge, it's not impossible.

- DNA sequencers cost about one to two million dollars each. Reportedly, a single research institute in China has 128 of them, along with supercomputers, and finding intelligence genes is a high priority. Reportedly, they have over 4,000 scientists and technicians working there.

- Intelligence genes may not be missing for long. The more genetics is responsible for intelligence, the more likely we will understand the underlying neurobiology and the more likely we can find ways to improve intelligence.

Suggested Reading

Bouchard, "Genetic Influence on Human Intelligence (Spearman's G)."

———, "IQ and Human Intelligence."

Chiang, Barysheva, and McMahon, et al., "Gene Network Effects on Brain Microstructure."

Chiang, Barysheva, and Shattuck, et al., “Genetics of Brain Fiber Architecture.”

Deary, Penke, and Johnson, “The Neuroscience of Human Intelligence Differences.”

Gottfredson, “Mainstream Science on Intelligence.”

———, “What If the Hereditarian Hypothesis Is True?”

Hunt, *Human Intelligence*.

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Questions to Consider

Do genes limit a person’s intelligence?

What is epigenetics?

Can We See Intelligence in the Brain?

Lecture 8

Brain imaging studies helped shift intelligence research away from predominately psychometric approaches, and the controversies about them, to a more neuroscientific perspective because imaging provided a way to determine how psychometric test scores were related to measurable brain characteristics. In this lecture, you will learn about positron emission tomography (PET) and how it was used to study intelligence over nearly two decades. In modern intelligence research, there are other even more amazing imaging technologies, and they show the brain in even greater detail than PET.

PET Scans of the Brain

- In the early 1970s, brain researchers who studied humans were limited to investigating brain function indirectly by looking at blood and urine for by-products of neurotransmitter activity. The only useful technology was based on measuring the electrical activity of the brain using EEG recordings from scalp electrodes. Some progress was being made with EEG studies of intelligence, but getting beyond the scalp, through the skull, and inside the living brain for research was not really practical.

- Positron emission tomography (PET) scans show brain function. Radioactive glucose accumulates in brain areas working the hardest, which show up on the scan. By contrast, a computerized axial tomography (CAT) scan shows only brain structure as X-rays pass through the head. You can see a beautiful, detailed CAT scan of a person's brain, but you cannot tell from the scan if the person is awake or asleep—or even if they are alive or dead. CAT scans show structure, but not function.

- A PET scan looks different depending on what the brain is doing. If you inject the radioactive glucose while a person is solving reasoning problems, for example, you can see the brain areas that


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PET scanners have been used by researchers to study intelligence for decades.

are at work for reasoning, and you can measure just how hard those areas are working.

- The first PET scanners became available in about 1980, but only a few were put into service. The whole operation was extremely complex, and the first scan done at a PET facility cost a few million dollars. Magnetic resonance imaging (MRI), now so familiar, was not yet available. The first MRI scanners came to research centers in about 1995.

- In the early 1980s, most of the PET research was on schizophrenia and psychiatric disorders. Most research scans were charged at about $2,500 each. PET scans for psychological studies were rare.

PET Studies of Intelligence

- In 1988, the first PET study of intelligence was published. It found brain areas that were more active while problem solving, but—very surprisingly—more brain activity was associated with worse performance. This counterintuitive result suggested that it's not how

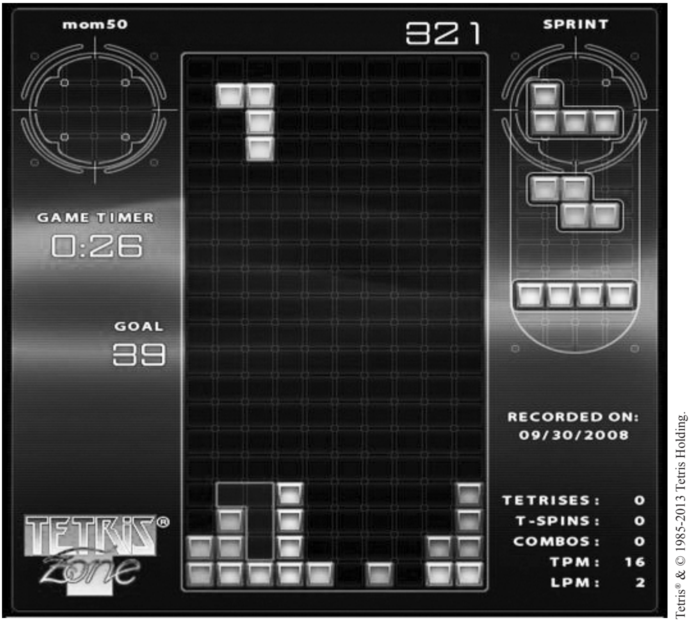
hard your brain works that makes you smart; it's how efficiently it works. Based on this result, the researchers proposed the brain efficiency hypothesis of intelligence: that higher intelligence requires less brainwork.

- Since this surprising finding in 1988, many researchers have been trying to understand how exactly brain efficiency might relate to intelligence. How can learning make the brain more efficient? When you learn something—like driving a car, for example—doesn't your brain get more efficient so that you now can drive and have a conversation at the same time, something that was not possible that very first day you were driving back and forth in an empty parking lot?

- One of the first PET studies of learning, which took place in the early 1990s, involved Tetris, a computer game that is now one of the most popular games of all time. In this study, a small number of college-aged male volunteers were scanned before and after 50 days of practice on the original Tetris version.

- In Tetris, different shapes appear at the top of the screen and slowly fall to the bottom. You can move them right or left, rotate them, or drop them immediately by pressing buttons. The object is to place each shape so that the shapes together form perfect rows with no gaps at the bottom of the screen. When you complete a row, it disappears, and all of the shapes above drop down. The better you do, the faster the shapes drop, so with practice, the game is faster and harder. The game is over when the shapes not in rows stack up to the top.

- On day zero, the first time any of the students ever played Tetris, they completed 10 rows per game on average while the radioactive sugar was labeling their brains during the first PET scan. This increased to nearly 100 rows per game during their second scan after the practice period. At the end of the 50 days of practice, some of the games were moving so fast that you could scarcely believe a human being could make and execute decisions so quickly.



Tetris is a computer game that involves strategy, mental rotation of objects, and reaction time.

- After 50 days of practice, the scans showed less brain activity after practice even though the game was faster and harder. Therefore, the brain learned what areas not to use and became more efficient with practice. In addition, the smartest people became the most brain efficient after practice. Other subsequent studies have shown inconsistent results, so the jury is still out on this point. Many other studies, however, have replicated decreased brain activity after learning, which is consistent with the brain efficiency hypothesis.

- Efficiency could result from activity within neurons, glial cells, synapses, or white matter fibers that transmit signals around the brain—or some combination. Neural pruning, which refers to the normal course of brain development, might also be a factor. From birth to about age five, there is a dramatic increase in the number

of synapses; then, there is a dramatic decrease, which is called neural pruning.

- The pruning mechanisms are still not clear. For example, the rate of neural pruning may be largely under genetic control, but could stimulating brain areas by learning increase pruning and influence intelligence? We don't know.

Male-Female Brain Differences

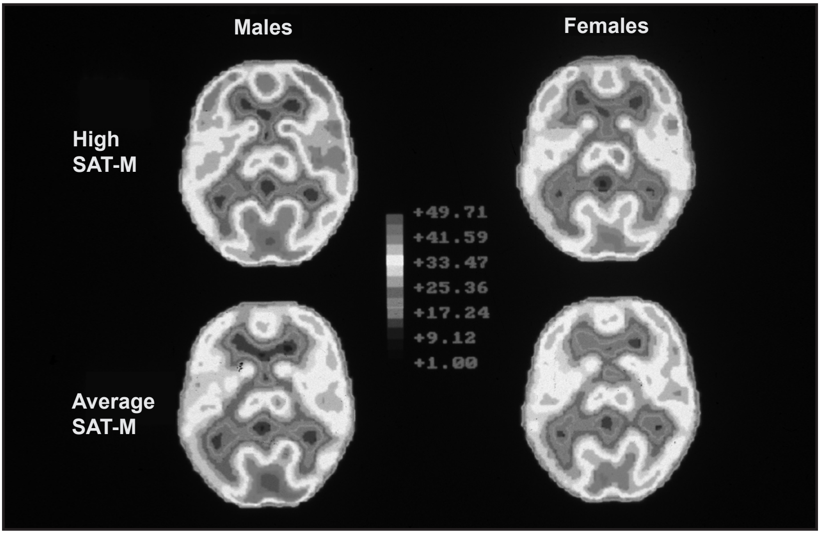
- In 1995, researchers used PET to see if men and women both showed equal brain efficiency in the same brain areas while they solved mathematical reasoning problems. Male and female college students were recruited based on their SAT-M scores at admission, and four groups were selected: men with high SAT-M scores, over 700; women with equally high scores, over 700; men with average SAT-M scores, in the 500 range; and women with average scores, in the same 500 range. There were 11 students in each group.

- Each person completed a PET scan while they solved actual SAT-M reasoning problems. Researchers expected to see lower brain activity in both the high SAT-M men and the high SAT-M women compared to the average groups—consistent with brain efficiency. They also expected that the men and women in the high group might show efficiency in different brain areas because there are sex differences in brain size and structure.

- The averaged PET scans in each group don't look all that different. In the men, statistical analysis showed that high math ability correlated with greater activity in the temporal lobes, or the side parts of the brain, during the problem solving—just the opposite of efficiency. In the women, researchers found no statistical relationship at all between math ability and activity anywhere in the brain.

- How the brains in the high SAT-M women were working during solving the same problems as the men is a mystery. In addition, the men showed the opposite of what was expected. This finding was

Male vs. Female SAT Scores



one of the first clear indications from imaging data that men and women may process information and problem solve with different brain networks.

- In this study, the men and women were equally matched on SAT-M scores, and they solved the problems during the scan equally well. Their brains, however, showed really different patterns of activity.

- The results of this study imply that not all brains work the same way. This may seem obvious and even trite, but at the time of the study, most cognitive researchers were interested in discovering how brains work in general, assuming that all brains basically work the same way. A focus on individual differences and the idea that not all brains work the same way was not so popular.

- Remember that math ability is a specific factor; it's not *g*. Brain efficiency may be related to *g*, but for specific abilities like math, better performance may require more brain activity. In general, it

is important to realize that no story about the brain is simple, and it takes many studies and many years to sort things out.

- Around the year 2000, a PET study was conducted on college students while they passively watched videos with no problem solving required. Researchers correlated brain activity during this non-problem-solving condition to IQ scores. The correlations are in several areas—none in frontal lobes and most in the back of the brain.

- The results of this study indicate that people with higher IQ scores seemed to be viewing videos with different brain activity than lower-IQ people, especially in the back of the brain, where basic information is perceived. This implies that smarter people may be more engaged and actively processing the video information differently. In other words, the smarter brains were not so passive. This is more evidence that not all brains work the same way.

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Deary, Penke, and Johnson, "The Neuroscience of Human Intelligence Differences."

Gottfredson, "Mainstream Science on Intelligence."

Haier, "What Does a Smart Brain Look Like?"

Haier, Chueh, Touchette, and Lott, et al., "Brain Size and Cerebral Glucose Metabolic Rate."

Haier, Siegel, Jr., and MacLachlan, et al., "Regional Glucose Metabolic Changes."

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Hunt, *Human Intelligence*.

Jensen, *The* g *Factor*.

Jung and Haier, "The Parieto-Frontal Integration Theory (P-FIT) of Intelligence."

Neisser, Boodoo, and Bouchard, et al., "Intelligence."

Neubauer and Fink, "Intelligence and Neural Efficiency."

Sternberg, Lautrey, and Lubart, *Models of Intelligence.*

Questions to Consider

What does it mean to show that intelligence test scores are related to brain function?

How can less brain activity be related to higher intelligence?

What Brain Imaging Reveals about Intelligence

Lecture 9

Brain imaging involves the measurement of how specific brain areas communicate with each other during complex thinking and reasoning. Researchers are making comparisons among people with different cognitive abilities and, most importantly, testing hypotheses about how an intelligent brain works. In this lecture, you will learn about the emerging models of brain function and brain structure that may be the keys to answering the question of where intelligence is in the brain.

MRI Scans

- Protons naturally spin around an axis, and the spinning creates a weak magnetic field. Each proton axis has a different random orientation. If protons enter a strong magnetic field, they snap into the same north-south alignment.

- If a radio wave is pulsed on and off rapidly into the magnetic field, the protons snap out of alignment and then back in; this pulsing can be done many times per second. As the protons snap in and out of alignment, the shifts give off weak energy, and this energy can be detected and mapped, showing where the protons are if the magnetic field is applied along a gradient of different intensities. This sequence of events is called magnetic resonance imaging, or MRI.

- Hydrogen protons are abundant in water, and most of the body—especially the brain—is made of water, so MRI gives beautiful images of the body and the brain. MRI scanners look like large donut-like devices containing a very powerful magnet. When a person lies on the bed and the head or whole body goes into the center tube-like area, radio waves are rapidly pulsed into the magnetic field, and the protons in the body snap in and out of alignment (the person has no sensation of this snapping). The shifting energy patterns formed by all of this snapping are detected and mathematically turned into a picture.


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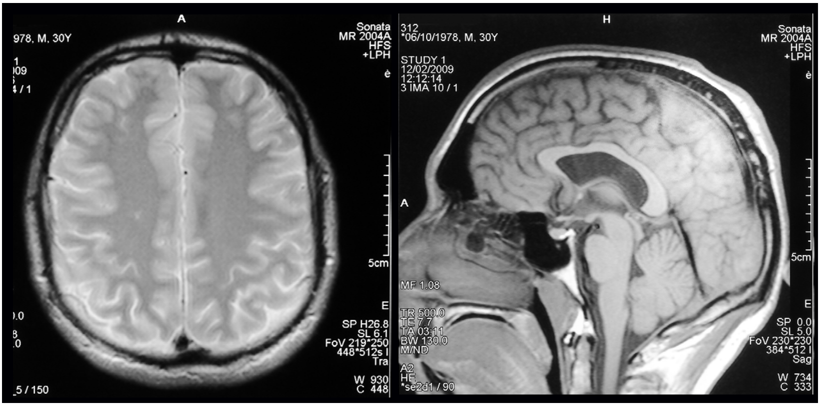
MRI scanners use a three-dimensional imaging technique to scan the brain.

- The basic MRI technique is quite versatile: By changing various parameters of the scanning sequence—for example, the frequency of the radio wave pulses—different kinds of pictures can be made that emphasize different brain characteristics.

- These images are more detailed than the older CAT scans, and whereas CAT scans were made with X-rays, there is no radiation exposure at all during MRI. This is why every hospital has MRI machines and why many more researchers have access to MRI than they had to PET.

- The three kinds of MRI that have been used to study intelligence are structural, functional, and diffusion tensor imaging. Structural images show gray matter, where neurons work, and the white matter fibers that link brain areas and carry information around the brain. Gray matter and white matter tissue have different water content, so they can be distinguished in these images. Note that structural



Brain scans can show researchers a lot about their subjects' mental processes.

images do not contain any functional information, so you cannot look at a structural MRI and tell if the person is awake or asleep, solving math problems, or even alive or dead.

- Like PET scans, functional MRI (fMRI) shows brain activity, but it's based on blood flow. Functional MRI uses scanning parameters that image aspects of hemoglobin in red blood cells. A sequence of very rapid images is made—thousands per second—that are interpreted as showing blood flow in the brain; those areas that are most active have greater blood flow. Whereas PET scans show the accumulation of brain activity over 32 minutes, fMRI scans show activity changes that last a second or two.

- With diffusion tensor imaging (DTI), the MRI sequences are optimized to image white matter fibers, and combined with special mathematical algorithms, the resulting images show white matter tracts in great detail, and the DTI measures assess the integrity of the tracts—that is, how well they transmit signals.

- The main method for analyzing MRIs, which can be used on structural, functional, or DTI images, is called voxel-based morphometry (VBM). There are three basic steps: First, we start

with an MRI image. Then, mathematical algorithms determine the boundaries of gray and white matter tissue. Finally, values are calculated that reflect the amount of gray or white matter tissue in each voxel in the whole brain. Because there are millions of voxels in the whole brain image, you get a very large data set. You can then correlate a test score, for example, to every one of these voxels and identify where the correlations are statistically significant.

MRIs and Intelligence

- Researchers used VBM to correlate gray and white matter tissue to IQ scores in a sample of volunteers. Based on WAIS IQ scores, the results for a group of 47 people showed that the largest areas of the brain related to IQ are in the frontal lobes, but there are also several smaller areas toward the back of the brain that are related to IQ. This is further evidence that intelligence does not depend on the frontal lobes alone.

- Surprisingly, when researchers analyzed the data separately for men and women, they found that in men, the largest brain areas where more gray matter correlated with higher IQ were in the back, especially in a part of the parietal lobe related to visual-spatial processing. However, in women, almost all of the areas where gray matter correlated to IQ were in the frontal lobe, especially around a part of the brain related to language called Broca's area.

- These results are consistent with the idea that men and women may have different brain areas related to *g*. In other words, not all brains work the same. In addition, the gray matter areas related to IQ appear to be under genetic control.

- In addition to conducting research based on WAIS IQ scores, researchers have also looked at the correlations between gray matter volume and scores on the individual subtests of the WAIS. The subtests have different *g*-loadings—that is, some tests are more related to the *g*-factor than other tests. The higher the *g*-loading of a subtest, the more brain areas showed correlations with gray matter.

The P-FIT Theory of Intelligence

- By 2006, there were 37 imaging studies of intelligence from different research groups around the world. Despite using different imaging methods and different intelligence tests, there were consistent findings. The result of a review of these various intelligence studies is a model of brain-intelligence relationships called the parieto-frontal integration theory (P-FIT) of intelligence.

- As a result of this model, areas of the brain were discovered that define a general brain network and subnetworks that underlie intelligence. Most of the areas are in the frontal and parietal lobes, but there are also some in the left hemisphere, some in the right, and some in both hemispheres. At least one frontal area is deeper in the brain.

- A major white matter tract of fibers deep in the brain connects the frontal and parietal lobes like a superhighway. It's called the arcuate fasciculus, and it seems to be an important tract for intelligence because it integrates information flow between frontal and parietal areas.

- The way information flows around these areas seems to be the basis for individual differences in intelligence. Some people will have more efficient information flow and score higher on intelligence tests, and others will be less efficient and less good at problem solving.

- The basic idea of this model is that the intelligent brain integrates sensory information in back areas, and then the information is further integrated to higher-level processing as it flows to frontal areas. Some P-FIT areas in the front and back of the brain are areas related to memory, attention, and language—suggesting that intelligence is built on these fundamental cognitive processes.

- The P-FIT also suggests that any one person need not have all of these areas engaged to be intelligent; several combinations may produce the same level of general intelligence, but with different strengths and weaknesses for other cognitive factors.

- Since the review of 37 studies was published in 2007, there are now more than 100 imaging studies of intelligence from research groups all over the world. Overall, the emerging evidence supports the basic P-FIT model.

MEG Imaging

- One of the newest brain imaging technologies that may have even greater potential than DTI is called the magnetoencephalogram (MEG). MEG data shows brain activity millisecond by millisecond as neuron magnetic fields fluctuate. In fact, there are many brain areas involved during one second of activity. MEG technology not only shows which areas of the brain are activated, but it also shows the sequence of areas that become involved as the brain works on even a simple decision.

- Researchers are analyzing MEG data and relating activation patterns to intelligence scores to see if high- and low-IQ individuals show the same sequence of activation across brain areas. If they do, is the sequence any faster in the high-IQ people? Alternatively, high-IQ people may show patterns with shortcuts, engaging fewer brain areas than lower-IQ people.

- Researchers are working with MEG imaging in several ways, and this seems to be a cutting edge of brain imaging research on intelligence.

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Chiang, Barysheva, and McMahon, et al., "Gene Network Effects on Brain Microstructure."

Chiang, Barysheva, and Shattuck, et al., "Genetics of Brain Fiber Architecture and Intellectual Performance."

Colom, Haier, and Head, et al., "Gray Matter Correlates of Fluid, Crystallized, and Spatial Intelligence."

Colom, Jung, and Haier, "Distributed Brain Sites for the *g*-Factor of Intelligence."

Colom, Karama, Jung, and Haier, “Human Intelligence and Brain Networks.”

Deary, Penke, and Johnson, “The Neuroscience of Human Intelligence Differences.”

Glascher, Rudrauf, and Colom, et al., “Distributed Neural System for General Intelligence.”

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Hunt, *Human Intelligence*.

Jensen, *The* g *Factor*.

Jung and Haier, “The Parieto-Frontal Integration Theory (P-FIT) of Intelligence.”

Neisser, Boodoo, and Bouchard, et al., “Intelligence.”

Neubauer and Fink, “Intelligence and Neural Efficiency.”

Sternberg, Lautrey, and Lubart, *Models of Intelligence.*

Questions to Consider

Why does brain imaging move intelligence research in new directions?

What can we see and what can’t we see in brain images of intelligence?

Intelligence and the Brains of Children

Lecture 10

In this lecture, you will be introduced to some key research about intelligence and the brains of children and adolescents. There are three basic questions that will be considered in regard to brain development: What aspects of brain development are related to intelligence? Are these developmental factors essentially the same for everyone? Is there a critical period when these factors can be influenced? This lecture will review several imaging studies that address these questions.

High versus Normal IQ in Adolescents

- In PET scans of male and female college students doing math reasoning during imaging, data for the men showed that activation in the temporal lobes was correlated to math score. In another study, adolescent males selected for high math ability completed functional MRI while they solved problems that required three-dimensional, visual-spatial problem solving.

- The key to these kinds of problems is the ability to mentally rotate objects in 3-D space in one's head. This kind of visual-spatial rotation ability is an important intelligence factor that emerges in studies based on factor analysis, and it is related to mathematical ability.

- When mathematically gifted adolescents were solving these problems during functional MRI, their brain activations were greater and more extensive than controls with average math ability. Like the PET study using the SAT-Math, more activation is apparent for the high-ability group, and the increases are somewhat consistent with a frontal-parietal network—but not perfectly.

- In a study of Korean high school students, all of the students completed the Raven's test of abstract reasoning. All of the students also completed functional MRI while they did simple problems and again while they did complex problems. The researchers

subtracted the brain activations during the simple problems from the activations during the complex problems. The difference in activation between the complex and simple problem solving was determined for the left and right hemispheres. The areas of the brain that were activated are in frontal and parietal areas and are consistent with the P-FIT model.

- In this study, half of the students were selected for high scores on the Raven's test, and the other half were selected for average scores. The results showed activation in the parietal area for the high-scoring students; activation increases are strongly correlated to Raven's score. Individual differences in brain activity in this specific parietal area predict individual differences in Raven's scores.

- This relationship was not found for the frontal lobes, which suggests that the frontal parietal network communication related to intelligence may be driven by activity more in the parietal areas. However, more research is needed in this area.

Brain Development in Children

- There is no question that brain development is rapid and complex in the first few months and years of a child's life. Whatever effects the early environment or early education may have on intelligence, those effects happen in the brain, and brain imaging in children is beginning to identify how brain development and intelligence are related.

- In a large collaborative study from the National Institutes of Health (NIH), researchers scanned a representative sample of over 300 children and young adults with structural MRI. Each participant completed a battery of cognitive tests, including IQ tests. Many of the participants have been rescanned and retested on different occasions as they age.

- One of the first papers from this study reported a surprising relationship between cortical thickness and IQ. In young children, there is a negative correlation; in other words, the thinner the cortex, the higher the IQ. However, this negative correlation turns

positive in late childhood, where a thicker cortex is associated with higher IQ. In fact, the correlations between cortical thickness and IQ are even stronger in late childhood than in early adolescence or early adulthood.

- The authors of this study suggest that intelligence is related to rate of cortical thickening rather than to just amount of gray matter tissue, and there may be a period of brain maturation during which critical circuits for intelligence develop. This is an intriguing finding, but like everything else, it needs replication.

- Another study from 2009 was based on a different NIH sample of 216 children between the ages of six and 18. Researchers from several medical centers recruited these children from across the country to be a representative sample of the U.S. population. The children were not patients. They all completed IQ testing and structural MRI. Researchers used these data to test whether brain areas in the P-FIT model showed correlations between IQ and cortical thickness.

- There were significant correlations for the whole sample of 216 children, and all of the correlations were positive—greater thickness correlated with higher IQ. Overall, several P-FIT areas showed cortical thickness–IQ correlations, especially in the adolescents, and to a lesser extent in the younger children. However, correlations were also found in brain areas not part of the P-FIT model.

- These analyses did not report a relationship between thinner cortex and IQ in the youngest children. This kind of inconsistency is not uncommon among studies, and that's why no single study ever settles any issue about the brain. Even in children, brain areas related to IQ are distributed throughout the brain, and there seems to be a developmental sequence for which brain areas are related to intelligence as the brain matures.

- In a newer study of 115 children between the ages of six and eight from the Netherlands, children completed functional MRI during

The brain scans of young children are used to study developmental aspects of intelligence.

a resting state as well as a nonverbal intelligence test. Researchers selected a target brain area and then correlated brain activity in that area to activity in other brain areas.

- They found that greater connectivity between frontal and parietal areas in the right hemisphere correlated to IQ in these young children. However, this was not true for the network in the left hemisphere. Therefore, the researchers concluded that the P-FIT model appears to characterize young children, at least in the right hemisphere. There was also some indication that the findings were stronger in girls.

- A series of important brain imaging studies in children have been done by Vincent Schmithorst and his colleagues at the Cincinnati Children's Hospital Medical Center. These studies include hundreds of children who are not patients, and several of the studies specifically set out to compare boys and girls.

- Through these studies, for boys, a greater association was shown between intelligence and the functional connectivity linking a frontal lobe area important for language—called Broca's area—to auditory processing areas in the back part of the brain, including the parietal lobe.

- For girls, a greater association was shown between intelligence and the functional connectivity linking parts of the temporal lobe to the same areas in the back of the brain. Frontal lobe connectivity was not as important for intelligence in the girls. Therefore, the linkage between frontal and parietal networks was apparent in the boys, but a different network was apparent in the girls.

- In a different analysis of more than 100 of the children who completed diffusion tensor imaging, the Cincinnati group found IQ relationships to white matter tracts that connect frontal and parietal areas, including the arcuate fasciculus. Girls had positive correlations between IQ and a measure of white matter reliability (or integrity), and boys had a negative correlation.

- For now, the meaning of the opposite direction of these relationships is a mystery. The Cincinnati studies also indicate that, even in young children, male and female brains have different developmental sequences for structure and function related to intelligence.

Critical Periods for Brain Development

- If critical periods exist for intelligence, then we need to know specific factors that are important for optimal brain development. One of the most interesting examples of a critical period in human development involves language. Research done at the University of Washington in Seattle by Patricia Kuhl illustrates what may be happening, in part, for intelligence.

- Kuhl has conducted a large series of experiments with infants learning language. The following are four of the key findings.
    - Hearing a language results in neuron development, especially how neurons connect with each other to form networks, and

this development optimizes the brain for perceiving the sounds of the language. This happens specifically in the brain's auditory areas.

  - These brain changes happen by six months of age.

  - If the infant is not exposed to the sounds of a language during this time, learning a new language almost always results in a distinctive accent.

  - Hearing the language from a human produces more brain changes than hearing the language from a television.

- Hearing a language fosters network connections in the auditory cortex in parts of the parietal lobe where some of the Cincinnati studies found relationships to intelligence. In addition, several P-FIT areas are related to language, and language ability certainly is related to the verbal factor of intelligence. Therefore, hearing a language in the first months of life may influence later intelligence.

- There is no direct evidence of this, but there is research that suggests that just the number of words spoken in the household before age two predicts IQ at age three—and the number of words spoken in a household varies tremendously. In addition, the number of words spoken is confounded with the IQ of the parents, so causality is not clear.

Suggested Reading

Gottfredson, "Mainstream Science on Intelligence."

Hunt, *Human Intelligence*.

Jensen, *The* g *Factor*.

Karama, Ad-Dab'bagh, and Haier, et al., "Positive Association between Cognitive Ability and Cortical Thickness."

Karama, Colom, and Haier, et al., "Cortical Thickness Correlates."

Neisser, Boodoo, and Bouchard, et al., "Intelligence."

Schmithorst and Holland, "Functional MRI Evidence."

Shaw, Greenstein, and Lerch, et al., "Intellectual Ability and Cortical Development."

Sternberg, Lautrey, and Lubart, *Models of Intelligence.*

Questions to Consider

Is there a critical period of brain development related to intelligence?

Do boys and girls have different brain development?

Sex and Intelligence

Lecture 11

This lecture confronts some controversial data regarding intelligence differences between men and women. In this lecture, you will be introduced to three issues in this area. First, you will learn that there are some sex differences in mental abilities, and you will discover what they are. Then, this lecture will address whether the sex differences have any important implications. Finally, this lecture will cause you to ask whether the sex differences in some mental abilities are related to sex differences in the brain.

Gender Differences and Mental Abilities

- Until fairly recently, women were actively discouraged from pursuing advanced degrees in the STEM fields, which include science, technology, engineering, and math. This discrimination was partly based on stereotypes about the proper role of women in society and partly based on the perception that women didn't have the mental abilities required for these fields.

- The former point is powerful, but at least it's open to correction if a society chooses to challenge stereotypes—but what about the second point? If the second point is actually true, and women and men differ on mental abilities, what then? It's really this latter point that is the most contentious.

- When we look at measures of general intelligence, the data is clear: There are no average intelligence differences between men and women. Partly, this is due to the fact that in the development of the major IQ tests, individual items that differentiated males and females were dropped from the test, but there is considerable research using other measures of *g* that did not follow this practice, and the results are the same: No difference in average IQ scores between males and females.

- However, even with the same means, the actual intelligence distributions for males and for females are a bit different. In male-female comparisons, although the overall group mean is the same for boys and girls, there are slightly more girls in the middle parts of the distribution, and there are slightly more boys at each extreme end. In other words, boys are slightly overrepresented in the low-IQ end of the curve and also slightly overrepresented at the high end.

- What about the more specific intelligence factors other than *g*? There are some specific mental abilities that do show consistent average differences. The following is a partial list from research complied by Diane Halpern; the list is from the latest 2012 edition of her book *Sex Differences in Cognitive Abilities*.
    - Women are better than men on verbal fluency, fine motor tasks, and writing.

    - Men are better than women on tasks that require transformations in visuospatial working memory, tasks that involve moving objects, motor tasks that require aiming, and tests of mathematical and scientific reasoning.

Do the Differences Matter?

- Mental rotation is a specific mental ability that shows the largest average sex differences. Mental rotation is an important intelligence factor, especially for mathematical reasoning. The key to mental rotation is the ability to mentally rotate objects in 3-D space in one's head.

- On average, men outperform women on tests of mental rotation in 53 countries. It doesn't seem like there are major cultural differences, but there are many factors in studies like these, and the causes of these differences are not really clear. However, women outperform men, on average, in some specific spatial tests that do not require 3-D rotation. Overall, most of the average sex differences are small.

- The reasons for sex differences are not clear, but do such differences have any importance for understanding why women are

underrepresented in STEM careers? If you look at SAT-Math scores over a 25-year period, from 1986 to 2010, there is an increase in average scores for both groups, but there is also a 40-point gap that favors males that has remained fairly constant.

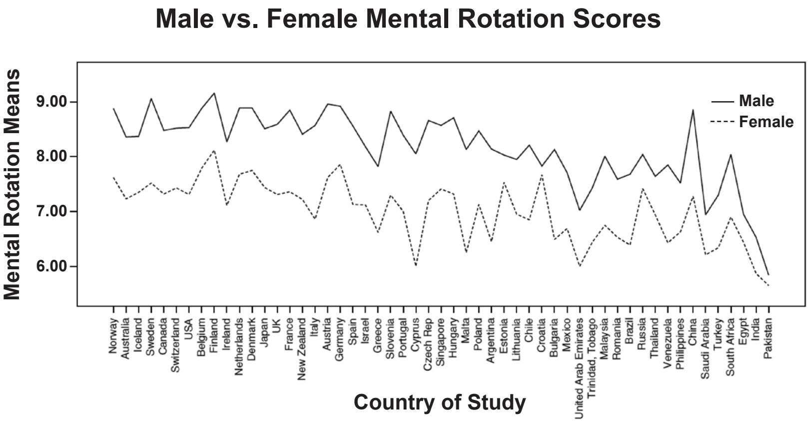
- The Hopkins study in 1972 found 13 precocious boys for every precocious girl. More recent talent searches based on the SAT now find ratios more like three to one. It is likely that the 1972 ratio of 13 to one was some kind of sampling error. The three-to-one ratio is still large, but certainly less shocking.

- Even small mean differences in distributions can result in larger disparities at the high end. We observe such a disparity now in STEM fields, but nothing about the data tells us anything about the causes of the differences.

- The controversy is about the right tail of the distribution and whether there is an underrepresentation of women at the highest end of the distribution for math and science test scores. A right shift may be the case for mathematical reasoning and one reason there are fewer women in STEM professions, but there is controversy about whether the right shift really exists—or whether it is a main factor.

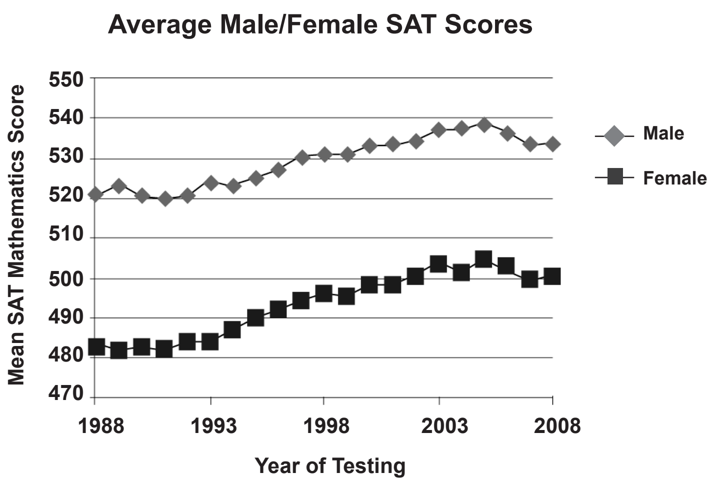
- There are other factors that may be more important. For example, surveys of women who excel at mathematics suggest that there is a tendency among these women to prefer careers that are more people-oriented than thing-oriented. People-oriented careers include medicine, law, and psychology; thing-oriented careers include physics, engineering, and STEM in general.

- A right shift may also be an artifact of the tests. Joshua Aronson is an expert on cultural influences on testing. He has special expertise in a phenomenon called stereotype threat, which basically means that if a person believes that he or she is not expected to do well on a type of test because of the group he or she belongs to, that person



won't do well on the test. Instead, he or she will perform like the stereotype suggests.

- There is considerable research on stereotype threat, but a key question is whether it can explain all of any test differences



between groups. Most research shows that it may explain some but not nearly all of a difference.

Gender Differences and the Brain

- There is some imaging evidence of brain differences between men and women—and between boys and girls—related to intelligence. We don't know the causes of these differences, but new research that combines imaging and genetic analyses offers some hope for answers. We just don't have them yet.

- There is some new data on the effects of testosterone on brain development that may provide clues about why there are some cognitive differences between men and women. This data shows that men and women do not differ on *g*, but they do differ on a small number of specific mental abilities—especially mental rotation. Brain differences may account for this, but we don't yet have a full picture of how any brain differences may develop.

- In the late 1960s and throughout the 1970s, any discussion or research on sex differences, especially for mental abilities, was quite controversial. It has become less controversial, and the existence of small average differences is widely acknowledged by the public. Funding for more research in this area, however, is difficult.

- There's a lot of pop psychology about how men and women think differently. For example, think about how men and woman generally approach shopping. It's a clear, everyday observation that men and woman have completely different thinking about shopping.

- We've seen some evidence that male and female brains may be organized differently from an early age. No matter how these differences may occur, think about implications of having different brain organizations for each of the following.

    - Rehabilitation after stroke or brain injury: There may be alternative brain pathways to accomplish the same cognitive performance.

    - Diagnosing and treating brain diseases like Alzheimer's: If the frontal lobes are more related to intelligence in women, then women may get a diagnosis of Alzheimer's later because the disease progresses to the frontal lobes later than other brain areas.

    - Countering aging effects: This may require different approaches in men and women.

    - Education strategies: It may be that certain styles of learning benefit one group, on average, more than the other.

- Understanding how any sex differences in the brain may influence these areas brings the study of sex differences out of the pop psychology realm and into neuroscience. The same is true when we try to understand whether there are any cognitive ability differences between men and women that are related, at least in part, to brain differences.

- Achievement gaps between men and women have largely disappeared in most careers, and the gap is closing in almost all areas. In various fields, including engineering, education, and life sciences, there has been a dramatic increase in the percentage of women. The role of spatial rotation ability is still not completely understood, but achievement gaps are clearly closing.

- Males and females differ on average for some mental abilities, and we are learning more about how male and female brains may work differently even when mental test performance is equal. Knowledge about such differences may prove useful for understanding how brain damage or brain disease may affect men and women differently. The good news is that male-female disparities in most vocations are decreasing or even eliminated.

Suggested Reading

Ceci and Williams, *Why Aren't More Women in Science?*

Gottfredson, "Mainstream Science on Intelligence."

Haier and Benbow, "Sex Differences and Lateralization."

Haier, Jung, and Yeo, et al., "The Neuroanatomy of General Intelligence."

Halpern, *Sex Differences in Cognitive Abilities*.

Hunt, *Human Intelligence*.

Jensen, *The* g *Factor*.

Neisser, Boodoo, and Bouchard, et al., "Intelligence."

Schmithorst and Holland, "Functional MRI Evidence."

Sommers, *The Science on Women in Science*.

Sternberg, Lautrey, and Lubart, *Models of Intelligence.*

Questions to Consider

Do men and women differ on the *g*-factor or other mental abilities?

Do male and female brains work the same way?

Race and Intelligence

Lecture 12

The topic of race differences in intelligence is probably the most difficult topic in psychology—even compared to issues regarding sex differences. In this lecture, you will be introduced to data about differences among groups for average SAT scores. Then, you will be introduced to similar data for IQ scores. This lecture will also examine the issues surrounding how achievement gaps and IQ gaps may be related and what may cause them.

The SAT Gap

- The data showing the gap between blacks and whites for both math and reading scores is troubling because of the large size of the gap and because the gap appears to be constant with no appreciable improvement over time. There are occasional reports that the gap is closing, but the overall data doesn't really show much if any narrowing of the black-white gap. There is virtually no disagreement about the existence of this gap; it is recognized as one of the most important problems in education.

- It's easy to assume that the gaps that exist for the SATs result from test bias. This is a primary basis for arguing that SAT scores should not be used as a principle factor in college admission, and in fact, most colleges and universities limit the role of SAT scores in the admissions process. The test bias argument, however, is not compelling. SAT scores were designed to predict academic success, and they do so equally well for students of all races.

- There are many other possible reasons for the gap that are more likely to be causes. These include poor education, poor home environment, poor test preparation, and poor motivation. Most people believe that factors like these are the main causes of the gap, and there have been earnest attempts to rectify these disadvantages to varying degrees.

- So far, however, the overall SAT gap remains fairly constant. It may be that good, solid programs to overcome many educational or other disadvantages so far have been implemented only for a tiny fraction of children that need them. There are many very good reasons to support such efforts—regardless of whether IQ scores are raised. Good schooling is obviously better than bad schooling and does not need justification based on whether intelligence test scores change.

- Even when there are improvements in elementary or high school, students who enter college with lower average SAT scores than their classmates have a much lower chance of academic success, especially in STEM majors. This is the so-called mismatch issue, and it is the subject of much debate.

The IQ Gap

- Psychometric tests of intelligence consistently show average differences among racial and ethnic groups. On average, Asians score higher than whites, whites score higher than Hispanics, and Hispanics score higher than blacks. The average black-white difference is about 15 points—about one standard deviation on the normal curve, essentially the same difference as the SAT gap.

- One standard deviation is a large average difference. It means that there are more blacks than whites at the low end of the distribution and fewer at the high end. However, it is important to remember that this is an average difference. It does not mean that all whites are smarter than all blacks.

- In fact, there is considerable overlap between the distributions. You cannot infer from an IQ score whether a person is a member of one race or another. This is a key point because the overlap demands that each person be treated as an individual and not stereotyped by group membership.

- There are some obvious factors that may cause these average differences in IQ scores, and they are essentially the same as the factors thought to cause the SAT gaps: test bias, poor education,

poor home environment, poor motivation, and poor test-taking skills. A common belief is that the differences must be due mostly to IQ test bias. The racial gap was used as evidence of test bias, and this resulted in a ban on using IQ tests in school.

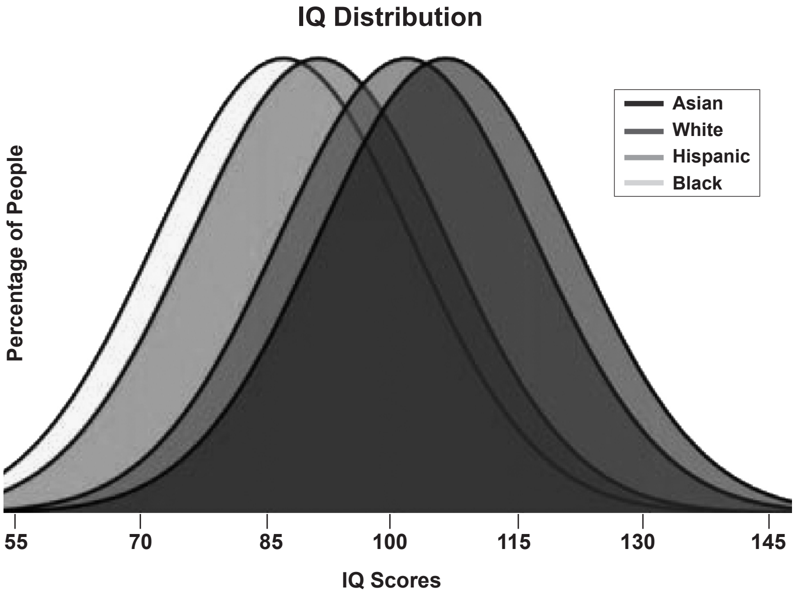
- Test bias has been studied extensively for four decades. The bias argument might predict that the general information subtest would show the greatest group difference because poor education would result in having less information; in fact, however, the general information subtest shows hardly any difference.

- One of the subtests with the largest group difference is digit span, which involves how many digits a person can repeat from memory. However, this is even more interesting because the group difference is not in the part of the test that involves repeating digits in order; the largest difference is in repeating digits backward.

- Data collected from public school children by Arthur Jensen in the early 1970s show that digit span forward scores for black and white children, who were broken down into groups based on a social class index, were not much different between blacks and whites. However, scores increase for both groups as social economic status increases.

- Digit span backward is a test that involves repeating a string of digits in reverse order after hearing them. For this test, there are clear differences that are consistent for each social class category. Again, scores increase as the social class index increases. Social class is a complex variable, and it is typically confounded with parents' IQ. More intelligent parents receive more education, earn more, and provide more resources for their children.

- Digit span backward has a high *g*-loading; digit span forward and general information subtests have lower *g*-loadings. Overall, the largest black-white differences tend to be on tests with higher *g*-loadings. Data like these suggest, but don't prove, that test bias is



not the major factor in group differences. Not all researchers accept this interpretation.

- Another kind of test bias, however, is supported somewhat by studies of stereotype threat. Stereotype threat studies of many varieties basically show that blacks score lower when they are told that a test measures intelligence.

- Stereotype threat indicates possible anxiety-related bias, but it accounts for only a small portion of the one-standard-deviation difference, and it's not clear how to prevent someone from thinking that an intelligence test is not really an intelligence test. While these studies support a certain kind of possible test bias, most researchers doubt that they account for the whole gap.

- There are disagreements about the interpretation of much of the data regarding the gaps. In 1995, the American Psychological Association (APA) had a committee review all of the relevant data,

and they concluded that the average IQ differences among racial groups were not easily explained away by test bias. Environmental disadvantages also were obvious possible explanations, but they too failed to account fully for the gaps.

- Reasoning tests like the SAT are types of intelligence tests, and the total SAT score from all sections is an estimate of *g*, so it's possible that the SAT gap and the IQ test gap may be two sides of the same coin.

- If there is a genetic component to intelligence, then there may be a genetic component to the intelligence gaps among races. Logically, this is not an unreasonable train of thought, but it implies that some groups may have a genetic advantage over other groups for intelligence. This idea is about as inflammatory as it gets.

The School Achievement Gap

- In addition to his controversial conclusion about the apparent failure of compensatory education, Arthur Jensen was the person who explicitly tied education achievement gaps directly to intelligence gaps in his 1969 article. He directly raised the possibility that a part of the school achievement gap might be due to the genetic component of general intelligence.

- Jensen's view is actually a simple one: Whatever factors cause the difference between low and high intelligence in individuals—whether genetic or environmental or epigenetic interactions—they are the same factors for all groups. He calls this the default hypothesis. Jensen, and virtually all other intelligence researchers, support maximizing educational opportunities for all children irrespective of race.

- In 1969, when Jensen proposed the idea that part of the achievement gap may be due to genetic components of intelligence, almost everyone was appalled at this suggestion. If we consider that whatever the genetic component of intelligence may be, it also may be a factor for group differences, then this is especially

controversial if you believe that anything genetic is determined and unchangeable.

- However, genetics may not be so deterministic, especially if we can identify specific gene-environment interactions. Nevertheless, the idea that genes play any role in the average group IQ differences is difficult to accept for most people. Many critics have argued against this view. In fact, some researchers have argued that the study of group differences is inherently racist.

- The main reason for more research on these issues is that there is a large, serious school achievement gap among groups that most people would like to eliminate. To solve the problem, we need to understand all aspects of it—even if the data leads in uncomfortable directions. Absence of data is also a prejudice.

- There are fair criticisms to be made about the hypothesis that the IQ gaps may be due in part to genetics. Given all of the various viewpoints, the majority of researchers in the field believe that the most likely explanations for the race gaps involve several factors, including environmental, genetic, and epigenetic. Of course, this is so general that it seems a cop-out, but the short, simple truth is that we don't really know with any certainty why these gaps exist.

- This was the conclusion of the APA committee in 1995, and it is still true today. The lack of progress is due to the lack of funding for research related to these sensitive issues and to the unwillingness of most researchers to get involved in these controversies.

Suggested Reading

Dickens and Flynn, "Black Americans Reduce the Racial IQ Gap."

Flynn, *What Is Intelligence?*

Gottfredson, "Mainstream Science on Intelligence."

Hunt, *Human Intelligence*.

Jensen, “How Much Can We Boost IQ and Scholastic Achievement?”

———, *The* g *Factor*.

Miele, *Intelligence, Race, and Genetics*.

Neisser, Boodoo, and Bouchard, et al., “Intelligence.”

Nisbett, *Intelligence and How to Get It*.

Sternberg, Lautrey, and Lubart, *Models of Intelligence.*

Questions to Consider

What are group differences in IQ?

What is the most likely explanation for group differences in IQ?

Are We Really Getting Smarter?

Lecture 13

In terms of the *g*-factor, are people today any more intelligent then they were 200 years ago? What about 2,000 years ago? We have data for the last 100 years, and it seems like people are getting smarter. In fact, intelligence test scores have been rising from generation to generation since they were first introduced. This trend is known as the Flynn effect. In this lecture, you will learn that while there is broad agreement among researchers that this is a real phenomenon, many issues about the effect are still unresolved.

The Flynn Effect

- Researchers have determined what the average IQ score would be for each year when the norms from 1918 are used to calculate the scores for all subsequent years. In 1918, the mean was 100, but the mean was 125 in 1995 using the old 1918 norms. In other words, it looks like people are getting smarter from generation to generation.

- If 1995 norms are used, the 1995 mean was 100, but the 1918 mean IQ for the population would have been 75 if 1995 norms were used. In other words, the average IQ in 1918 would have been in the mentally retarded range by the 1995 standard. Obviously, most people were not mentally retarded in 1918. This illustrates a serious problem with IQ scores if norms are not updated periodically. However, when the same norms are used, it looks like IQ is increasing from decade to decade.

- A large number of data sets from around the world going back decades show that there is a clear trend of increasing intelligence scores. This phenomenon is called the Flynn effect, and it presents a challenge to the standard *g* model.

- If intelligence scores are fairly stable over a person's lifetime, and if genetics is so important for intelligence, then how can scores be increasing so much over just 100 years? James Flynn, a professor of political philosophy in New Zealand, is the person who has written most about this—especially in his 2007 book called *What Is Intelligence?*.

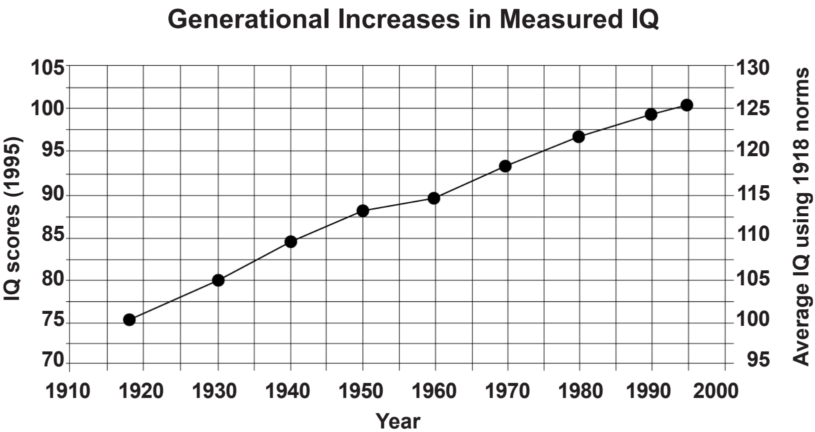
- Flynn's story starts in 1984, when he became interested in the stability of IQ scores. Over time, Flynn has reviewed IQ data from many studies going back to the turn of the 20th century, when intelligence testing records began. He found a very clear trend of increasing scores. He also discovered that the tests with the highest *g*-loadings were not always the ones that showed the greatest gains. The picture is mixed.

- Various data from numerous studies show a Flynn effect even for top students, and the effect is apparent for boys and for girls. However, the effect is limited mostly to math scores. Clearly, data about the Flynn effect raise many questions. There are many, many data sets, and now there are many researchers looking at them. Therefore, there are disagreements about how to interpret the same data.

- The key issue is whether the Flynn effect is mostly for *g* or non-*g* tests. Many critics of IQ testing and the *g* concept immediately and enthusiastically embraced the idea that IQ scores are increasing from generation to generation.

- The Flynn effect is popular among critics of *g* because critics reasoned that such a large increase could not occur so quickly if IQ was mostly genetic. Genes are subject to evolution over very long periods of time, so three or four generations are far too short to see genetic changes. Therefore, for many critics, the Flynn effect was proof that environment factors must have considerably more influence on intelligence than the genetic data indicated.

- However, if the gains are mostly for low *g*-loaded tests, there can be explanations that do not challenge the concept of *g* or the importance



of genetics. Various research studies show mixed and inconsistent findings about whether the Flynn effect is mostly a *g* effect or not. A key issue is whether increased test scores reflect better test-taking skills or an actual increase in the *g*-factor. Disentangling these two possibilities in research studies is quite difficult. So far, the evidence is not clear one way or the other. The following are some other important unresolved issues about the Flynn effect.

- ○ Is the effect greater for people with lower scores?
- ○ Is the effect the same size in different countries?
- ○ Is the effect still operating now as strongly as it did 100 years ago?
- ○ Will the effect continue in the future?

- All of these issues depend in some way on what may be causing the basic Flynn effect.

Changes in Society and the Flynn Effect

- There are many changes in society over the last 100 years that may be causing the increase in intelligence test scores, including that

the world has become more industrialized, mass communication has spread, nutrition has generally improved, and education has increased for more people. Of course, more than one factor can be involved.

- The common thread among these possibilities is that largely because of science and technology, and mass media, people are much more experienced with abstract—rather than concrete—approaches to problem solving. This experience could affect brain development in ways that increase intelligence. This general idea is certainly reasonable, and it gives rise to many testable hypotheses.

- There is a large body of data, but so far, the data do not present a uniformly consistent picture. The bottom line is that we still do not know specifically what causes the Flynn effect. If we did, we should be able to design ways to use those causal factors to increase intelligence even faster or more broadly.

- Nevertheless, Flynn has a number of ideas about these issues. First, it's important to understand that Flynn is not anti-*g*; he acknowledges that the *g* model explains much data accumulated from thousands of studies, and the *g* model has provided an important framework for testing many hypotheses over the years. However, he sees the Flynn effect as data that is not easily explained by the *g* model.

- Flynn regards the *g*-factor as a snapshot at any given time extracted from a battery of mental ability tests, but he argues that the individual mental abilities can change independently of *g*, and they depend on social context and trends. Therefore, while a person's *g* may be stable, the elements that contribute to *g* may change. In fact, some tests show a much larger Flynn effect than other tests.

- Flynn offers an alternative model to the *g* model, which he calls BIS: The "B" stands for "brain," the "I" stands for "individual differences," and the "S" stands for "social trends." All three work together to influence intelligence.

- Flynn takes the view that social and cultural factors are the most important influences on brain development and on individual differences in intelligence. He is less convinced that genes are involved in the racial gaps, and he is optimistic that the gaps will close as social and cultural disadvantages are minimized. He is particularly concerned with poor language skills in early life.

- There are many critics of Flynn's model and his interpretation of results, but regardless, Flynn has helped us rethink our ideas about intelligence. It is an overreach to argue that the Flynn effect disproves a major role for genetics, as some critics do. It's fair to say that many, if not most, researchers take either an explicit or an implicit view of intelligence based on epigenetic concepts.

- Whatever the environmental and sociocultural factors of the Flynn effect may be, they must act through the neurobiology of the brain with whatever the genetic factors may be. In other words, genes provide basic brain parameters for intelligence and IQ, and the *g*-factor, but other factors influence how the genetic potential unfolds. The Flynn effect indicates that those factors include social and cultural factors, but whether these factors influence *g* is not clear.

- The Flynn effect has caused a constructive reexamination of some basic views about intelligence. For the most part, the parameters of the Flynn effect are still a puzzle, and the causes are still a mystery. Whether the factors that underlie the Flynn effect can be used to influence an individual's intelligence within a single life span remains to be seen.

- It may also be the case that we will never understand the Flynn effect because of the limitations of intelligence tests to measure the *g*-factor in a true quantitative way, like we measure temperature or liquids. There are some potential new approaches to measuring intelligence that may avoid the problems with current tests.

- A new brain imaging study that was conducted in London and published in 2011 measured changing IQ scores in the teenage years

and found that while intelligence is fairly stable over a lifetime, there are some important caveats—especially in the teenage years. Like the Flynn effect, however, the factors that cause fluctuations in intelligence are not clear. They could be related to schooling or many other concurrent social factors. Of course, there are also many biological changes during these years.

- If intelligence is less stable than has been believed, we need to identify the things that influence change—perhaps better nutrition and increasing exposure to television, computer games, and other complexities of the modern world. Then, we can investigate the biological mechanisms for how they influence the brain.

Suggested Reading

Flynn, *What Is Intelligence?*

Gottfredson, "Mainstream Science on Intelligence."

Hunt, *Human Intelligence*.

Jensen, *The* g *Factor*.

Neisser, Boodoo, and Bouchard, et al., "Intelligence."

Ramsden, Richardson, and Josse, et al., "Verbal and Non-Verbal Intelligence Changes."

Sternberg, Lautrey, and Lubart, *Models of Intelligence.*

Questions to Consider

What is the Flynn effect, and what may cause it?

Has the Flynn effect stopped?

The Mind in Milliseconds

Lecture 14

In this lecture, you will learn about some alternative ways to think about measuring intelligence based on how fast the brain processes information. These methods avoid the critical problem of IQ points not being able to be measured like temperature degrees or liters of liquid. It turns out that we can measure the mind in real units with perceptual tasks. As we learn more and more about the brain and how it processes information, we get closer to seeing intelligence in neurophysiological terms, and once we understand the neurophysiology, we may be able to modify it to enhance intelligence.

Perceptual Tasks

- Perceptual tasks will surely appeal to you if you think you're not a good test taker. In a simple perceptual task, you will see a simple figure flash on a computer screen very quickly. This figure will flash on a computer screen many times; each flash is called a trial. For example, the figure might be composed of two lines, one of which is shorter than the other. Sometimes, the long side of the figure will be on the left, and sometimes the long side will be on the right.

- All you do is press one button if the long side is on the right or another button if the long side is on the left. You simply press the button of your choice as fast as you can each time the figure flashes.

- For each trial, as soon as the figure flashes off, another figure appears immediately—with heavy lines of equal length on both sides, for example. This figure is called a mask. It always is the same, and its purpose is to mask any lingering image of the other figure on your retina so that your decision is not influenced by any trace of the image after it flashes off.

- Here's what makes this simple perceptual task a test: The first flash lasts a fairly long time—about a full second. It's very difficult to make a mistake about which side is longer when the figure stays

on for a second. But as the trials continue, each flash stays on for shorter and shorter amounts of time.

- When the flashes reach about a half of a second, or 500 milliseconds, people start making mistakes. The flashes continue to be briefer and briefer, until the shortest period the flash stays on is determined where the person maintains a criterion like 75 percent accuracy. This shortest period of getting the side correct is called inspection time, or the briefest time you can perceive which line is longer.

- It turns out that people differ on inspection time: Some people can perceive the lengths of the lines with very brief flashes, and other people need longer flashes to see the lines. It also is the case that inspection time is reliable in that the same person tested on two occasions shows the same value. Identical twins also have similar inspection times.

- Inspection time correlates to IQ scores. People with higher IQ scores have faster inspection times. The correlation is about 0.5, which is a moderate correlation, but it's not really strong enough to be an actual intelligence test.

Inspection Time

- The point is that a simple perceptual task is correlated with the much more complex IQ score. This raises the possibility that other tests of information processing may estimate intelligence even better. Such tests might be quick, easy, and cheaper to administer than psychometric tests, and inspection time may be less uninfluenced by culture and social factors.

- Intelligence test scores rank people relative to each other; they are ordinal measures, so there is no actual zero point, and the intervals between IQ points are not necessarily equal. IQ scores are not like pints or liters of liquid. However, time in milliseconds is a true metric. Each millisecond measures the same time interval. For example, 100 milliseconds is exactly twice 50 milliseconds. In addition, zero means zero. Time is a ratio scale, and a ratio scale is like pints or liters of liquid.

Inspection Time: Mask

- Measures of the time it takes the brain to perceive and process information have the potential to be actual measures of intelligence. The question is whether such measures are related to intelligence, and we see from research on inspection time that they are.

- In fact, long before studies of inspection time, there is an extensive history of measuring brain processing speed with reaction time. There is now a considerable interest in using reaction time as a possible alternative to psychometric tests of intelligence.

- Reaction time is simply the time it takes between a stimulus and a response. For example, a light flashes on, and you press a button as quickly as you can. The time between the light coming on and your button press is your reaction time.

- The scientific study of psychology in the late 19th century actually began with studies of reaction time, and to this day, response time experiments are mainstays of cognitive psychology. However, it was a problem of individual differences in perception and speed of processing that really brought attention to response time.

- There are now about 150 years of reaction-time experiments addressing issues about learning, memory, and attention, but most of them do not investigate individual differences. Interest in using reaction time to measure individual differences as they may relate to intelligence has more recent origins.

- Many thousands of children and adults have done many variations of tasks used to study response time. Overall, it turns out that the correlation between response time for a simple choice is correlated to intelligence test scores, but response time to more complex choices is more strongly correlated to intelligence test scores. In fact, if you add a battery of different response time tests to a battery of psychometric tests and do a factor analysis, the response time tests load on the *g*-factor. Movement time does not.

Mental Chronometry

- Arthur Jensen, who wrote a paper on compensatory education and group differences in IQ, also believed that psychometric intelligence tests could never resolve any of the core issues because these tests were limited to ranking individuals rather than measuring how brains function.

- Jensen was very much aware of brain imaging and its importance for intelligence research because it could measure brain structure and function in actual units, but he also was interested in developing response time measures as a more sophisticated measurement tool. He spent much of his later career developing what he called mental chronometry. The four basic ideas of mental chronometry are as follows.
    - Response time is correlated to measures of intelligence.

    - Response time is regarded as a measure of information processing speed.

    - Response time to different basic cognitive tasks can be used to assess individual differences in cognitive strengths and weaknesses.

- Standardized response time measures can substitute for intelligence tests.

- Jensen not only argued that it is time to focus research away from the traditional psychometric intelligence tests, but he also wanted to redefine intelligence in terms of information processing and assess it with response time tests. He went even further and suggested that it was time to replace the word "intelligence" with something more like "mental processing."

- One issue with mental chronometry is whether faster response time is a cause or a consequence of more intelligence. The bottom-up view is that faster brain processing results in higher intelligence. The top-down view is that higher intelligence results in faster processing. The data does not yet resolve which view is correct, but brain researchers generally tend to prefer bottom-up explanations.

- Another basic issue is why something as simple as response time in a fairly simple task—even a task that requires choices—is related to the far more complex problem solving tapped by psychometric tests. Critics of mental chronometry have proposed several possible reasons that explain away the basic correlation, but so far, none of the proposed alternative explanations have a compelling empirical basis.

- As of now, there is not yet a standardized response time assessment or battery of tests that could be the basis of a new science of mental chronometry, but there are researchers working on it.

Executive Function

- Although cognitive psychologists have focused their research primarily on general principles of learning; memory and attention; and basic, elemental cognitive processes like memory and attention, there is an important cognitive concept that addresses issues relevant to understanding intelligence. It is the concept of executive function.

- Executive function has an enormous research literature. The following is a basic summary.
    - Executive function refers to how the brain organizes all of the incoming sensory information.
    - Memory is a key component.
    - Attention is a key component.
    - Prioritizing is another component.
    - Decision making and taking action are the results of executive function.
- All of the elemental cognitive processes in executive function taken together may be thought of as intelligence—or, at least, as a framework for intelligence. This is partly the basis for Jensen's view that it is time to consider standardizing response times to basic cognitive processes as a way to understand intelligence.
- Interestingly, as more cognitive psychologists become interested in intelligence, there are some attempts to train people to perform basic cognitive tasks better, thereby increasing IQ.
- Another reason to think about tests of brain processing as possible measures of intelligence is because we know that perception and processing speed depend on some of the same brain areas that are related to intelligence. Brain data may someday be used to assess intelligence based on sequence and timing differences among people. It has some of the same advantages of mental chronometry, although it is more expensive and less practical.
- A new science of measuring intelligence is emerging, and these measures will not be bound by the limitations of interval scales like IQ tests. As in all scientific fields, new and better measures advance understanding and allow more sophisticated questions and theories to test.

Suggested Reading

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Deary, Simonotto, and Meyer, et al., "The Functional Anatomy of Inspection Time."

Gottfredson, "Mainstream Science on Intelligence."

Hunt, *Human Intelligence*.

Jensen, *Clocking the Mind*.

———, *The* g *Factor*.

Neisser, Boodoo, and Bouchard, et al., "Intelligence."

Petrill and Deary, "Inspection Time and Intelligence."

Sternberg, Lautrey, and Lubart, *Models of Intelligence.*

Questions to Consider

What does how fast you press a button when a light flashes have to do with intelligence?

How can brain processing speed be measured?

Creativity and Intelligence

Lecture 15

In this lecture, you will learn what the research shows about creativity and the brain. You will learn about some very rare cases in which brain damage or the onset of dementia has apparently unleashed creative genius that the person never had before—called acquired savant syndrome. This lecture will also address issues about defining and measuring creativity for scientific study, which are similar to those regarding intelligence. You will also learn about the relationship between creativity and intelligence, and you will examine brain imaging studies of creativity and what they show.

Acquired Savant Syndrome

- Cases of acquired savant syndrome, in which a person acquires a profound or prodigious ability after an accident, are exceedingly rare. Most of them are anecdotal, and researchers have investigated few in any systematic way. They are so rare that it is difficult to formulate any conclusions about them.

- There is reasonable skepticism about cases of acquired savant abilities, but there are two kinds of cases where artistic creativity emerged after specific, well-documented brain damage. Both kinds are extremely rare—even rarer than savants. One kind of acquired savant case involves strokes or brain aneurisms; the other kind involves a type of dementia called frontal temporal dementia.

- In 1988, a man named Jon Sarkin had a stroke when he was 35 years old. The left hemisphere of his brain was severely damaged, and to make matters worse, he developed life-threatening complications that caused surgeons to remove part of his left cerebellum. When he recovered, Jon began to create art and demonstrated a talent he apparently never had before.

- To complicate the story even more, Jon's artistic drive is obsessive and compulsive. Furthermore, Jon also developed bipolar disorder; his moods swing from mania to depression. Jon's intelligence, however, appears unaffected.

- Jon has undergone sophisticated brain imaging at Harvard, including diffusion tensor imaging. The conclusion was that Jon's brain had developed new connections from the remaining parts of the cerebellum to parts of the brain that were not usually connected to the cerebellum. How this happened is unknown, but it is an important hint about artistic creativity and brain connectivity.

- The second kind of brain damage that is associated with artistic creativity is a type of dementia called frontal temporal dementia. This is not Alzheimer's disease, but it is equally devastating—although not as common. In a few rare cases of frontal temporal dementia, the patient develops a completely new desire and ability to create art or music.

- There are some scientific papers published about creativity emerging in patients with frontal temporal dementia that include brain imaging. The general conclusion is that the subgroup of patients who have more deterioration in the left temporal lobe as the dementia progresses are the ones who are more likely to show new artistic or musical talent.

- The general idea is that temporal lobe deterioration disconnects pathways to the frontal lobes, and the frontal lobes become disinhibited. When your neurons are excited, they fire a pulse of information to other neurons. Inhibition stops excitation. The brain is constantly ebbing and flowing between excitation and inhibition. Disinhibition weakens inhibition and results in more excitation.

- Disinhibition of the frontal lobes also occurs with alcohol consumption and some drug use. It may be why LSD makes some people feel creative. Drugs that are used to induce anesthesia often create a stage of disinhibition just before loss of consciousness,

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After a major event, such as a stroke or accident, some people develop artistic or other abilities that they didn't have before the event.

when patients say all kinds of things. Dreaming may also be associated with disinhibition of frontal lobes.

Defining and Measuring Creativity for Scientific Study

- Even though savants are very rare, artistic ability is not unusual among savants. Creativity and artistic ability are not necessarily the same thing. Is the scientific study of creativity possible?

- On one hand, most research strongly supports the concept of a general factor of intelligence that is common to all mental abilities; on the other hand, savants demonstrate that individual mental abilities can exist independently of the general factor. Is creativity more like an independent general factor, common to various fields, or is it more like a specific mental ability? Are there different creativities, such as music, art, and science?

- We generally recognize intelligence when we see it, and we certainly easily recognize the lack of it, but is the same true for creativity? How is creativity different from intelligence?

- One widely accepted concept is that creativity typically involves the production of something novel and useful or valuable. However, usefulness is difficult to apply to art, for example, although art can be valuable both in terms of emotional enjoyment and in terms of money. Usefulness and value, of course, depend on the social context, which is always changing.

- The threshold theory basically says that an IQ above 120 is necessary for creativity. Over 120, some theorize that additional IQ doesn't increase creativity whereas others think the that most creativity is likely in the very highest IQ range. Data from follow-up studies of the Hopkins Study of Mathematically Precocious Youth support the idea that highest scores predict more creativity defined in terms of objective accomplishments, even at the very highest end of the distribution.

- The remote associates test is one of the tests that researchers use to measure creativity. This test assesses the ability to see unusual associations and connections between common things. Because the associations required are unusual, they are called remote associations.

- The following is a sample test item: What new word is associated with the words "cottage," "Swiss," and "cake"? The answer is cheese: cottage cheese, Swiss cheese, and cheesecake. There are wide individual differences among people on this test.

- This test requires basic knowledge that may or may not be current, but in addition to good vocabulary—which is correlated with IQ—you also need to be able to associate things that may not be obvious. Researchers think of this as at least one component of creativity.

- Another test is called the uses of objects test. Researchers use this test as a measure of divergent thinking—that is, what is often meant when you “think out of the box.” This test also taps the fluency of unusual ideas, which is another aspect of the creative process.

- The uses of objects test gives a person 60 seconds to list novel and creative uses of a common object—such as a brick, for example. The following are some ideas for using a brick: doorstop, water saver in a toilet tank, paperweight, bug smasher, and exercise weight. The actual test includes other items in addition to a brick, and a person’s responses are rated for creativity using standardized criteria. This test has also been used with brain imaging.

- A third test asks a person to think of creative captions for ambiguous pictures, which is actually quite difficult. These tests require ratings and some consensus about what is creative. This is really not as objective as most scores on intelligence tests—and certainly not like measuring temperature or liquids.

Creativity and the Brain

- There are many popular books about creativity and how to increase it or unleash it, but there does not seem to be compelling research that supports any measurable increase in creativity due to brain exercises. There is also a popular idea about creativity that focuses on a distinction between the right brain and the left brain. The general idea is that creativity comes from the right hemisphere and that rationality is a function of the left hemisphere. This idea is very general, and it is based mostly on patients with brain damage.

- As we know from functional brain imaging studies of intelligence, information flows throughout the entire brain. One hemisphere may be more involved than the other for any particular problem solving, but whether creativity depends more on the right hemisphere is still an open question that can be tested with brain imaging.

- Brain imaging studies of creativity are just getting started, probably because the tests and measures of creativity are not as well

developed as intelligence tests and measures. Whereas the *g*-factor has proved to be a useful framework for intelligence studies, there is not yet a comparable empirical finding for creativity. Even defining creativity is more difficult than defining intelligence.

- One of the first brain imaging studies of creativity measured the thickness of the cortex at many points throughout the brain and then correlated thickness to scores on a creativity index. This study found that gray matter in the cortex is related to a creativity index, suggesting that neuroscience investigations of creativity are possible. This is only one early study, and the results should not be overinterpreted, but there is additional evidence that brain structure is related to creativity.

- There are a number of functional imaging studies that have used various measures related to one or another aspect of creativity. The field is somewhat like the imaging studies of intelligence several years ago, when researchers extracted some common findings across disparate studies to formulate the P-FIT model.

Suggested Reading

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Jung and Haier, "Brain Imaging Studies of Intelligence and Creativity."

Jung, Grazioplene, and Haier, et al., "White Matter Integrity, Creativity, and Psychopathology."

Jung, Segall, and Haier, et al., "Neuroanatomy of Creativity."

Neisser, Boodoo, and Bouchard, et al., "Intelligence."

Simonton, *Origins of Genius*.

Sternberg, Lautrey, and Lubart, *Models of Intelligence.*

Questions to Consider

How is creativity defined for scientific studies?

Is there overlap between brain areas related to intelligence and brain areas related to creativity?

Can Intelligence Be Enhanced?
Lecture 16

Whether intelligence can be enhanced for anyone is really one of the greatest questions that exists in the field of neuroscience. It's at the heart of all intelligence research—either directly or indirectly. This lecture will introduce you to some promising approaches to this question. Specifically, you will learn about genetic and nongenetic approaches that are being researched with the aim of increasing intelligence or learning ability, mostly in adults.

Genetics and Brain Imaging

- Many countries are doing genetic research, and some research groups are combining genetics and brain imaging. One example is a large consortium of research groups from around the world working together to find gene-brain relationships that underlie mental illnesses and brain diseases. They are also looking at intelligence.

- This consortium is called ENIGMA (Enhancing Neuro Imaging Genetics through Meta-Analysis). They have pooled their databases and standardized their protocols. They now have over 21,000 individuals who have completed brain imaging with at least structural MRI and who also have contributed DNA samples. A subgroup has completed intelligence testing. Paul Thompson at UCLA is one of the principal investigators.

- One of the findings reported in 2012 was the identification of a gene that was related to brain size and to intelligence. The gene is called HMGA2, one of the first genes found in humans to be associated with higher intelligence test scores.

- They also reported another gene related to the size of the hippocampus, an important part of the brain related to memory. It, too, showed a relationship to intelligence scores—and the

relationship for both genes appeared to be stronger for nonverbal intelligence. These genes were found in samples from around the world.

- The ENIGMA findings are dramatic because of the size and scope of the database and because they were able to replicate these intelligence findings in independent samples. The actual associations between the genes and intelligence, however, were not all that strong. Most researchers now believe that there will be many genes like these identified, and each will contribute a small amount to intelligence. Whether these particular genes are sensitive to epigenetic influences is not yet known.

- We are at the beginning of tying specific genes to intelligence and learning how those genes function. This is the basis for eventual capabilities to influence the genetic mechanisms of intelligence, and it is why it seems like it will be possible to enhance intelligence, possibly dramatically, at some point in the future when we have an understanding of how the mechanisms work.

- This is the same sequence of scientific discovery that is the basis for finding genes related to specific diseases, learning how those genes work through biological mechanisms, and then finding ways to influence the biological mechanisms to prevent or treat the disease. Those ways could be by drugs or by lifestyle changes.

Nongenetic Approaches to Enhancing Intelligence: Memory Training

- There are approaches that are not based on genetic mechanisms that are being tested to enhance intelligence. One of these nongenetic approaches is based on memory training, and another is based on shocking the brain with electricity.

- In 2008, a group of cognitive psychologists at the University of Michigan were studying aspects of memory. They became interested in whether memory training improved general cognition—and possibly intelligence. There had been some suggestion in earlier studies that this might be the case.

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Touch-screen computer tablets allow people to rotate and explore DNA models in tangible ways.

- These psychologists studied 70 university students (males and females). Half were assigned to a memory-training group, and half were controls with no training. Training lasted eight to 19 days.

- All of the students completed intelligence testing with test items like the ones on the Raven's matrices test—which symbol completes the pattern in the matrix—with a 10-minute time limit. Each student took the tests before and after the training period or, for the controls, before and after the same number of days had passed.

- The question was whether the group who received the memory training had higher test scores after the training compared to the controls, who received no training. Higher scores would be calculated by subtracting the pre-training score from the post-training score, and then comparing the change to any change in the control group.

- The key question in this study is whether the intelligence test scores increased following this short-term-memory training. In other words, did improvement in short-term memory generalize to an increase in general intelligence?

- Intelligence test scores for pre- and post-training showed an average increase for the training group. There was a smaller increase for the control group after the same period of time. The more days of training, the greater the increase in intelligence score.

- The authors of this study concluded that short-term-memory training could enhance the kind of intelligence associated with reasoning and problem solving—key aspects of the *g*-factor.

- Critics of IQ and intelligence research jumped on these results as evidence that IQ was not fixed and could be enhanced with cognitive training. Many critics took the view that this demonstration of malleable intelligence undermined the genetic arguments, just like the Flynn effect did. The reasoning went that if simple cognitive training could increase IQ so dramatically, then underperforming school children could be trained to have higher IQs, and this would eliminate the achievement gap.

- However, there were some possible flaws in this study. For example, males and females were combined, so any sex effects were not investigated. More importantly, the Raven's matrices items require some short-term memory during the problem solving. The better your short-term memory, the more items you can finish in the allotted time. Therefore, training short-term memory is not completely independent of the test used to measure the outcome. Moreover, if intelligence is increased, the *g*-factor should be increased. To really assess *g*, however, a battery of tests needs to be given rather than a single test.

- The most critical problem with the interpretation that intelligence increased after training is that intelligence test scores are only interval scales. IQ points are not measurements like degrees of

temperature or liters of liquid, so the meaning of an increase in test scores alone is not clearly an increase in intelligence.

- Two of the principal authors of the 2008 University of Michigan study are cognitive psychologists Susann Jaeggi and Martin Bushkuel. They have subsequently published several studies replicating the findings and extending the same training effects even when a simpler memory test is used, and they have shown similar effects in children using child-friendly versions of the memory test.

- Overall, these studies argue that the training improves performance on tests that were not part of the training. In other words, the training improvements of short-term memory generalize to other test scores. However, the issue of whether intelligence increases is still open. It may not be possible to do a compelling study with current intelligence tests because they are not measures like temperature degrees or liters of liquid.

Nongenetic Approaches to Enhancing Intelligence: Shocking the Brain

- The idea that shocking the brain can enhance intelligence is an extension of a field called accelerated learning, and it's exactly what the name implies. If it takes at least 10,000 hours to develop expertise at any skill—from chess to tennis to flying a helicopter—wouldn't it be nice to find a way to cut that time dramatically? Accelerated learning is more of a desire than a reality, but there is some recent progress.

- DARPA, Defense Advanced Research Projects Agency, has funded some research on using a small, one-to-two-milliamp current to mildly shock the brain indirectly through electrodes on the scalp. The shocks can be delivered, for example, when there is a correct response during computer simulation training sessions.

- The mild shocks are thought to stimulate connections among brain areas, and there is some indication that the shocks result in better performance and faster learning. The technique is called

transcranial direct current stimulation. This is really in very early development, so do not try this at home; shocking the brain is not something to fool around with.

- However, if it actually works in research settings to increase learning, it may be possible to deliver more targeted stimulation directly to key brain areas related to intelligence—even using electrodes implanted into the brain, just like pacemakers for the heart or like implanted stimulators deep in the movement control areas of the brain now used for some people with Parkinson's disease.

- The brain areas identified in the P-FIT model could be targets for stimulation. There is some early research on this concept, using various methods to stimulate brain areas during learning and problem solving, but we don't know yet if this approach actually works.

- As with all brain research, the brain stimulation story is bound to be complicated, and negative effects could offset any positive effects. However, we might find ways to fix broken brain circuits for some cases of mental retardation or for some cases of learning disabilities.

Suggested Reading

Gottfredson, "Mainstream Science on Intelligence."

Hunt, *Human Intelligence*.

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Jensen, *The* g *Factor*.

Neisser, Boodoo, and Bouchard, et al., "Intelligence."

Stein, Medland, and Vasquez, et al., "Identification of Common Variants."

Sternberg, Lautrey, and Lubart, *Models of Intelligence.*

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Questions to Consider

Does brain training on mental abilities increase intelligence?

How could intelligence enhancement be done?

Intelligence, Child Rearing, and Education

Lecture 17

In this lecture, you will learn about music and computer games. The theme that ties these popular topics together is that, when it comes to increasing IQ in children or influencing education, there is less than meets the eye. You will also learn about the potential for using brain imaging in education to help optimize how children learn. The ability to increase intelligence—whether *g* or specific factors—raises controversial questions and many ethical and policy issues concerning education, child rearing, and society in general.

Music and IQ

- Decades of research have not provided any clear roadmap for parents or educators when it comes to specific ways for increasing or maximizing IQ, let alone the *g*-factor. The following are four points we can make based on where the research is so far.
  - There is a difference between intelligence and achievement.

  - Of the two, intelligence is less influenced by motivation and external factors like poor education and poor parenting, although there may be some effects on intelligence and possibly the *g*-factor, especially on brain development.

  - Preventing brain damage from environmental sources like poison exposure, poor nutrition, or head injuries can limit lower IQs.

  - Despite evidence that IQ scores have been rising and that teenage IQs fluctuate, so far, there is no proven way to increase intelligence with training or stimulation, although there is some evidence that some early education programs can improve study skills and academic motivation.

- There are two general assumptions that are guiding new research efforts. First, brain development in the first months of life, before preschool begins, is critical for language acquisition and likely for other key cognitive processes that underlie general intelligence and specific intelligence factors, but only within ranges set by genetic and epigenetic influences. Second, this means that each child already arrives at school with different patterns of cognitive strengths and weaknesses, so efforts to improve cognition need to be targeted in the early months and years of life.

- This is why there are now new, large research efforts to train or improve cognition aimed at children long before they get to preschool, especially disadvantaged children. These efforts often include computer games designed to target memory, attention, and problem solving, and some research studies now are including brain imaging to relate any test score improvements to brain changes.

- Based on existing research, there are a few general things that parents can do for optimal intelligence development in the first months and years of a child's life.
  - Breast-feeding may have small positive effects on IQ.

  - Good nutrition supports brain development in general, but specific foods to add or avoid are not clearly related to IQ, although there is some evidence that eating large amounts of junk food might decrease IQ scores slightly.

  - In the home environment, more exposure to language may foster cognitive development—even in infants. This includes talking and reading to children. However, for example, it is not clear that teaching your child to read very early has any effects on IQ scores.

- Teachers at preschools and elementary schools should encourage all kinds of mental activities but should understand that some children will respond better than others–no matter how they try to motivate them–because children come with different patterns of cognitive

strengths and weaknesses. These patterns are real and may limit a student's academic progress in certain areas. Even if you could determine these patterns of cognitive strengths and weaknesses for each child, it is not yet clear how to change them or how to use this information to maximize learning in a traditional classroom.

Neuroeducation

- A new term—"neuroeducation"—has appeared that implies that we may know more than we do about education and the brain. Neuroeducation programs are now marketed to school systems with the promise to increase learning ability, memory, attention, and even IQ. Most of these programs are based on various computer games designed to train and improve children's mental abilities.

- Research is underway to determine how effective such programs might be, but we don't yet have enough research to really know. However, we can comment on how neuroeducation programs should be evaluated before tax dollars are spent. The following are four general points about evaluation.
    - Educator-researcher cooperation is necessary on a higher level than just educators agreeing to give researchers access to students. Educators should know fundamental neuroscience and basic research methods—very few know either. This is a shortcoming of many teacher education programs that can be corrected.

    - Researchers must be able to communicate with educators; this is not really that easy because researchers tend to talk in technical jargon and often do not see educators as equal collaborators.

    - There is an important role for educational psychologists if they have been trained in research methods and have knowledge of modern developmental psychology and basic neuroscience. Educational psychologists are a logical group to bring educators and researchers together.

- ○ Parents need to be informed about what works and what doesn't based on research presented in understandable ways. This is a challenge for any school system, but success at this level is essential to bringing about any changes.

- A key concept to keep in mind while considering neuroeducation claims is that not all brains work the same. Each person has a different pattern of mental strengths and weaknesses, and students vary considerably on the *g*-factor. Therefore, any neuroeducational program may work for some students but not for others. Effectiveness might vary based on age, sex, current IQ, and socioeconomic status. Researching all of these possibilities and interactions is daunting but necessary.

- So far, research on outcomes of such programs tends to be limited to research done by the developers of the programs. Often, this research is not published in scientific journals subject to peer review. Independent replication of results is required.

Computer Games and Learning

- In the study in 1992 that involved the computer game Tetris, researchers used PET scans to see brain changes before and after college students practiced for 50 days. There was less brain activity after practice, which suggested that the brain became more efficient even though the game was moving faster and becoming more difficult with practice.

- Subsequent research by others indicated that practicing a task might result in an increase in gray matter in those parts of the brain that work on the task. An increase in gray matter in an area could result in decreased brain activity in that area because there would be more neurons to do the work, and that brain area would be more efficient.

- If computer game training improves cognition, we should be able to identify where and how the brain changes and whether the brain changes last over time or disappear when training stops.

- In 2009, the Tetris Company funded a replication of the 1992 findings. This time, researchers used both structural and functional MRI to study 13-year-old girls who had little experience or interest in computer games. In addition, a newer version of Tetris was used. The girls that were tested practiced this version for three months, and they became quite good.

- After practice, there were decreases in activity for both the left and right hemispheres. These findings replicated the previous finding of efficiency. There also were gray matter increases after practice. These findings were new and demonstrated a structural brain change after learning this task.

- The surprise was that there is no overlap between these brain changes, so efficiency does not appear to be related to increased gray matter. Why these two kinds of brain changes are unrelated is a mystery, but this level of understanding is required to validate any claims of cognitive improvement.

Neurometric and Chronometric Brain Profiles

- There seems to be potential for brain imaging to evaluate a student's profile of cognitive strengths and weaknesses and possibly suggest educational strategies to maximize that student's learning based on the student's brain image.

- Imagine that we have a very large, diverse group of individuals who get structural MRI scans. We could get the group average amount of gray matter in each P-FIT area, which is related to intelligence test scores. Assuming that the amount of gray matter in each area was normally distributed, some people would have more or less gray matter than the mean for each area. Some researchers refer to such brain quantification as neurometrics.

- Examples of neurometric brain profiles generally seem to have some validity in that the higher-IQ individuals have more gray matter in more brain areas that are thought to be related to intelligence.

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Studies of students playing computer games have led to surprising results regarding brain activity.

- We don't yet have enough data to know whether such brain profiles predict *g* or other intelligence factors—or special mental abilities—but this is research that is worth pursuing, especially if it potentially can help teachers design education strategies to maximize learning for every person based on how his or her particular brain is organized.

- How to change or improve a person's brain structure or organization are different issues. Once we have more brain imaging studies of creativity, a P-FIT-type model could be possible, and creativity profiles may be useful.

- Brain profiles could also be based on chronometrics—reaction times to different cognitive tasks measured in a standardized way. This may be cheaper and more practical than brain imaging, but research will need to compare effectiveness of each approach.

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Haier, “What Does a Smart Brain Look Like?”

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Neisser, Boodoo, and Bouchard, et al., “Intelligence.”

Sternberg, Lautrey, and Lubart, *Models of Intelligence.*

Questions to Consider

Can brain data help make decisions about the best way to maximize a child’s learning?

Should parents and educators be enthused or alarmed by talk of enhancing intelligence?

The IQ Pill

Lecture 18

This course has covered a lot of ground—from savants to factor analysis, from IQ tests to geniuses, from genetics to brain imaging, and from shocking the brain to some provocative implications of neuroscience approaches to intelligence research. Perhaps the most important and controversial question of all is the following: If we could raise intelligence, should we? For any individual, we might find ways to increase intelligence—especially in terms of the *g*-factor—if we understand the brain mechanisms involved. This leads to the implications of enhancing intelligence, which is the subject of this final lecture.

Cognitive Enhancement

- The term "cognitive enhancement" refers mostly to the use of drugs or food supplements to increase memory, attention, and learning. There is already considerable controversy about the use of drugs by students of all ages to get better test scores and higher grades.

- In the future, we will hopefully be able to go a step further and improve intelligence, especially the *g*-factor, and maybe even specific factors like spatial or mathematical ability. If we can do this someday, then the issues and controversies will be even more complicated than those regarding drug use related to academic testing.

- There is not much disagreement with the goal of maximizing every person's potential for learning, especially by improving environments—including diet. So many people use caffeine to get a mental boost that we hardly notice that this is drug use to increase mental performance. However, the use of stronger drugs to increase learning more dramatically is controversial.

- Similarly, the goal of changing a person's intellectual potential by tinkering with environments is fairly well accepted. That's

why early education programs are so popular, but tinkering with neurobiology is far more controversial.

- In many ways, the issue is the same as the issue of using drugs to enhance athletic ability. This is regarded as cheating because it is against the rules, but what if rules are changed to allow some kind of regulated drug enhancement?

- Although there are not yet really good memory-enhancing drugs, the following are some hypothetical questions for consideration if such drugs were to become available and had no negative side effects.
    - Is it cheating for a student to use drugs to enhance memory—especially if the enhancement was for long-term memory so that the learned material was not forgotten right after the exam?

    - Is it cheating for a stockbroker to use memory-enhancing drugs to keep track of many variables?

    - Is it cheating for an older manager to use memory-enhancing drugs to compete with younger employees?

    - If you think some of these circumstances are okay, how would you feel about the President of the United States using such drugs to help remember details of many complex issues?

    - Instead of memory, what about using drugs to improve attention or learning?

- The science journal *Nature* took a survey in 2008 of 1,427 scientists about drugs and cognitive enhancement. They found that 20 percent of the scientists already used drugs to improve concentration, 70 percent would risk mild side effects to boost brainpower, 80 percent defended the right to take such boosters, and more than 33 percent would feel pressure to give their children brain boosters if other kids used them.

- Cognitive enhancement with drugs for attention and learning is controversial. The following are some basic issues for debate.
  - Is it cheating?
  - Is it unnatural?
  - Is it drug abuse?
  - Is it safe?
  - Is it a matter of personal freedom?
  - Is access to it fair?
- The same issues are relevant if we could expand cognitive-enhancing drugs to include intelligence, *g*, or specific intelligence factors.

The Future of Using Drugs to Enhance Intelligence

- The concept of an IQ pill is metaphorical. It may be a drug that affects synaptic growth, neuron efficiency, gray matter thickness, or white matter integrity, or it may be a way to stimulate brain function with electricity or magnetic fields.

- Many drug companies are already working on new drugs to improve memory and learning for patients with Alzheimer's disease, but if these new drugs work in patients, could they also work in people without brain disease to enhance memory and learning—two of the key components of general intelligence?

- Few people would be against using such drugs if they improved cognition for people with Alzheimer's disease, stroke patients, inpatients with brain damage, or people with mental retardation—but what about people with no brain problems using such drugs?

- There are already drugs that improve attention in children with attention deficit disorder (ADD) like Adderall and Ritalin. Many parents want these drugs for non-ADD teenagers before they take

the SATs and other exams. These drugs are also in demand by many college students; estimates range from seven to 25 percent of college students use these drugs before exams. Despite their popularity, there doesn't seem to be any research that supports these uses. Nonetheless, the idea of cognitive enhancement seems to be not only acceptable, but there also seems to be a strong demand from parents as well as from students. The following are some questions about this topic.

  - Assuming no side effects, and knowing what you have learned about the importance of *g* in everyday life, would you take an IQ pill if it put you in the top one percent of people?

  - Assuming no side effects, would you give an IQ pill to your children if it put them in the top one percent of students?

  - If an IQ pill existed, and you could get it, and knowing that IQ is measured relative to other people, would you want everyone else to have equal access to it?

  - If an IQ pill existed, and it was not cheaply available to everyone, what would you be willing to pay for it?

  - If you had the pill, what would you want to do that you can't do now?

  - If you had a choice between an IQ pill and a pill that would dramatically increase your personal charisma, and you could only have one or the other, which would you choose?

  - If an IQ pill were possible, should the government ban it for any use?

- What if everyone were smarter by a half standard deviation—about seven or eight points? The normal distribution would shift to the right, so there would be more very bright people and fewer people at the low end, but there would still be a normal distribution. In

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If there were an IQ pill, many people would struggle with the ethics surrounding taking a drug to increase mental capacity.

some ways, this would be like accelerating the Flynn effect. Would there be anything bad about this?

- Higher IQ could go either way for any individual; some might use more intelligence for nefarious purposes, but we'd also have smarter police, so for society as a whole, it would probably be positive. However, if only some people had access to intelligence enhancement, what would be the consequences—especially if they could increase their IQs to over 150?

- We already have sociological evidence that our increasingly complex society is more divided than ever between the upper and lower groups, and intelligence differences clearly contribute to the disparities. It's possible that someday, and perhaps not that far off, the ability to enhance intelligence will be real, and there will be many problems to discuss and work out—just like many

other social problems introduced by other advances in science and medicine.

- More scientific information is almost always better than less, even when the findings go against our common beliefs or our personal interests. The key to scientific progress is to go where the data takes you. Ignorance and prejudice flourish in the absence of information.

- Nature is the way it is, no matter how we think it should be, but once empirical facts become known through scientific inquiry, there is always the possibility of changing nature. In the long run, this is how civilization progresses and how we help improve the quality of life for everyone.

- Research is always a work in progress; no single study can answer complex questions, and there are always more questions than answers. The following are some research questions about brain-intelligence relationships for the near future, each of which would require an extensive research program.
  - Regarding the brain, how does gray and white matter develop and change in ways related to intelligence?

  - How is information processed throughout the brain differently in high- and low-IQ individuals?

  - Are there properties of individual neurons that influence intelligence?

  - Can we increase *g* by stimulating the brain by any means—from increased language exposure to drugs to electrical shocks?

Suggested Reading

Gottfredson, "Mainstream Science on Intelligence."

Hunt, *Human Intelligence*.

Jensen, *The* g *Factor*.

Maher, “Poll Results: Look Who’s Doping.”

Neisser, Boodoo, and Bouchard, et al., “Intelligence.”

Sternberg, Lautrey, and Lubart, *Models of Intelligence.*

Questions to Consider

Do we have a moral obligation to increase intelligence if we could?

Would you take an IQ pill or give one to your children?

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